ODICAL
3(2)
13(2)

気象庁欧文海洋報告

第13巻 第2号

THE OCEANOGRAPHICAL MAGAZINE

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Vol. 13 No. 2

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Published by the Japan Meteorological Agency

March 1962

The Oceanographical Magazine
Vol 13. No.2, March 1962

The Monthly Mean Sea-Surface Temperature in the Northwestern Pacific

By

Jotaro MASUZAWA, Takeo TSUCHIDA and Tamio INOUE

Japan Meteorological Agency

(Received October 25, 1961)

The monthly mean sea-surface temperature charts in the seas adjacent to Japan have been made both by the Imperial Fisheries Experimental Station (at present, the Takai Regional Fisheries Research Laboratory, UDA and OKAMOTO, 1930, 31) and by the Kobe Marine Observatory (TSUKUDA, 1938 and NAKAYAMA, 1951), based upon the data before World War II.

Since 1946, the Oceanographical Section of the Japan Meteorological Agency has been collecting the sea-water temperature data taken on the board of oceanographic research vessels, fishing boats and merchant ships, and the section has published them regularly every ten-days as the Ten-day Marine Report. This report always includes the ten days mean sea-surface temperature chart of the Northwestern Pacific. Before July 1956 the isotherms had been drawn on the basis of original data of sea-surface temperature during ten days, while after that time they have been done on the basis of mean temperature of every one-degree square of latitude and longitude. The collection of data had been restained to the smaller area of 11°–47°N, 118°–165°E before March 1956, while it has been enlarged to 7°–50°N, 115°–180°E since April 1956. However, most of charts before 1949 are only available in the coastal region near Japan for scanty of data. Therefore, for the calculation of the monthly mean temperature we made use of the data during ten years from 1950 to 1959 in the area of 18°–46°N, 117°–165°E.

The monthly mean sea-surface temperature charts shown here are not based upon the observed values themselves, but upon the ten-days mean temperature charts. That is, we read the value at the center of every one-degree square on the ten-days mean temperature chart, from which three mean values

of the first, middle and last ten-days of each month are calculated. The monthly mean is the average of these three ten-days means.

Characteristic features of monthly mean temperature

It is easily recognized on the monthly mean charts that the isotherms are generally parallel to the latitude, with the exception of those at the East China Sea, at the Kuroshio current region from the Ryukyu Islands to the south of Japan and at the Oyashio current region southeast of Hokkaido. The north-south temperature gradient is greatest at the oceanic polar frontal zone, which is rather south in winter and north in summer. In the subtropical region south of 35°N, the north-south temperature gradient is generally smaller all the year round. At the region south of 25°N, however, it is a little greater in winter.

The annual range generally becomes larger as the latitude goes higher. The most ranges more than 18°C are found in the northern East China Sea and at the south of Hokkaido. In general the Northwestern Pacific is one of the areas with the most remarkable seasonal variation in the Pacific, because there prevails a typical monsoon system which gives great effects upon sea-surface temperature through evaporation and conduction, especially in winter. Since the East China Sea is as shallow as serval dozens of meters, the monsoon effects upon the sea water temperature are revealed almost to the bottom. Next as the Oyashio cold water goes down to the south of Hokkaido, the sea-surface temperature south of Hokkaido is lower than 2°C in winter, while in summer the radiation heat from sky is condensed in the surface layer owing to the great vertical stability, so that the sea-surface temperature becomes quite higher. Besides, in summer the surface warm water is transported from the south by southerly prevailing winds. This may be the principal reason why the annual range of sea-surface temperature is large in the south of Hokkaido.

Comparing our monthly mean temperatures with those published by the U. S. Navy Hydrographic Office (1943), ours are one or two degrees in Centigrade higher than those of the U. S. Navy, H. O. in the cold half year. This might be in part due to the climatic characteristics in the secular changes that the warmer winter happened at the period of our statistics (SUDA, 1961).

Chronological temperature anomalies

Based on the above-mentioned monthly mean temperature chart, the mean anomalies at the following five areas have been calculated.

Area	A	B	C	D	E
Lat. (°N)	20 – 25	25 – 30	30 – 35	35 – 40	40 – 45
Long. (°E)	125 – 135	130 – 140	140 – 145	145 – 160	150 – 165

We can recognize some significant characteristics in the chronological temperature anomalies. The positive anomalies happened in 1954 at the subtropical area, while the most remarkably positive anomalies occured in 1955–56 at the subarctic area. It has not so far been clarified whether there might be something to be correlated with among these two positive anomalies, or not. On the other hand, the definitely negative anomalies can be seen in 1953–1954 at the area to the north of 30°N. Since it has been pointed out that the climate of Northern Japan was cooler in 1953 and warmer in 1955–56 than usual, both the most negative anomaly in 1953 and the most positive anomaly in 1955–56 at the northern area might have some relations to the fluctuation of the general circulation of atmosphere.

References

NAKAYAMA, I. (1951): On the mean surface temperature of the neighbouring sea of Japan. *Mem. Kobe Mar. Observ.*, 159.

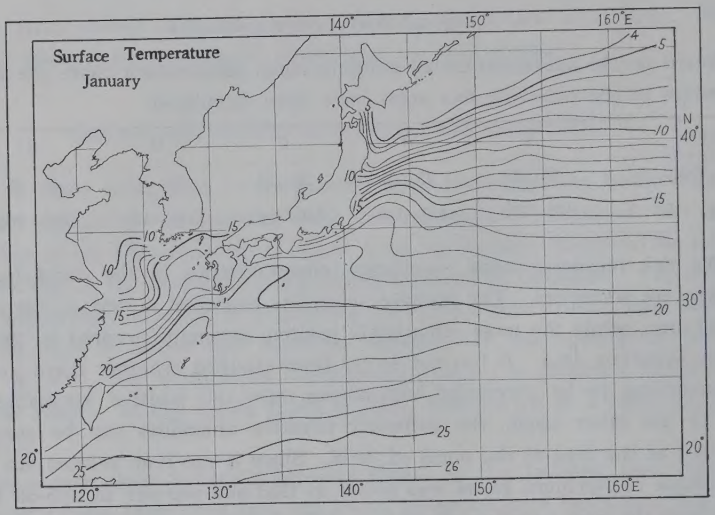
SUDA, K. (1961): Recent climatic changes. *Weather Service Bulletin. J.M.A.*, **28** (4), 140—144.

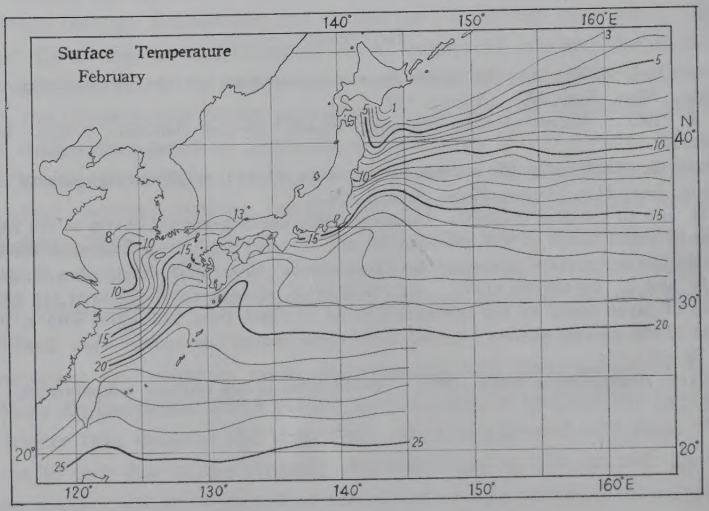
TSUKUDA, K. (1938): On the surface temperature of the neighbouring seas of Japan. *Mem. Imp. Mar. Observ. Kobe.*, **6**, 239—254.

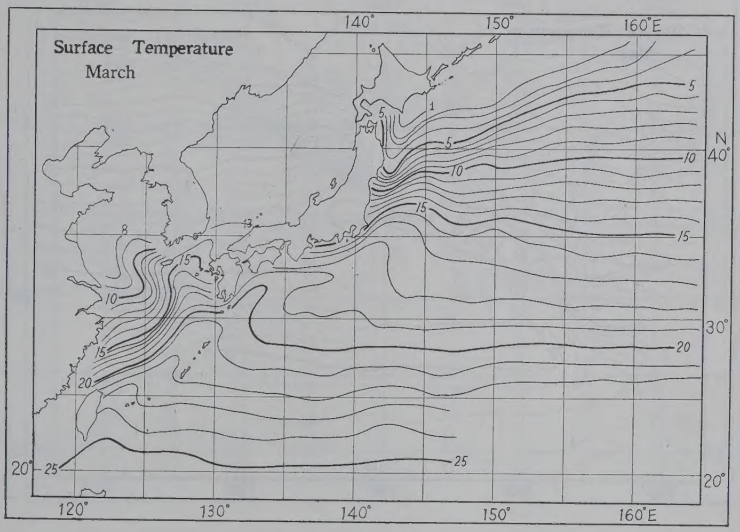
UDA, M. and G. OKAMOTO (1930): On the monthly oceanographical charts of the adjacent seas of Japan based on the averages for the 11 years from 1918—1929 with discussion of the current-system inferred from these charts. *Jour. Fish. Exper. Sta.*, **1**. 39—54.

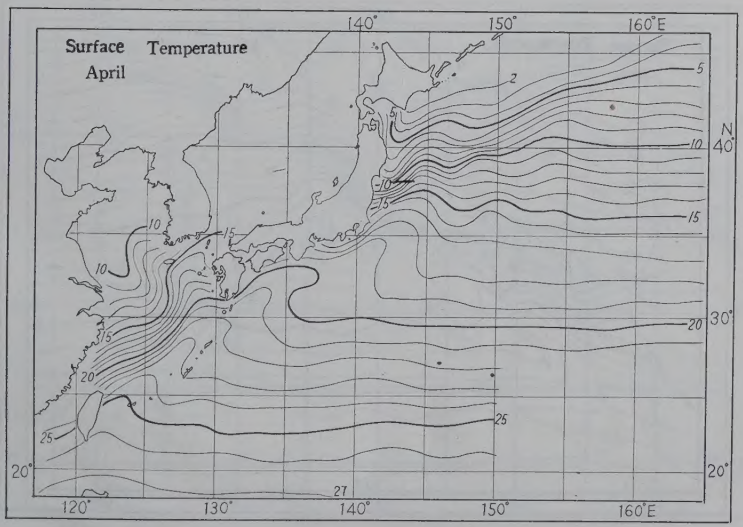
UDA, M. and G. OKAMOTO (1931): On the monthly oceanographic charts of the adjacent seas of Japan based on the averages for the 13 years from 1918—1930 with a discussion of the current system inferred from these charts. *Jour. Imp. Fish. Exper. Sta.*, **2**, 59—79.

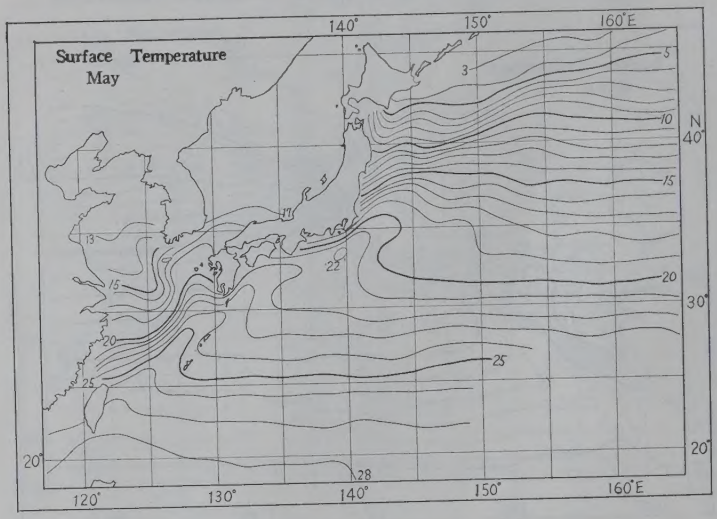
U. S. Navy, Hydrographic Office (1945): World atlas of sea surface temperatures. H. O. No. 225.

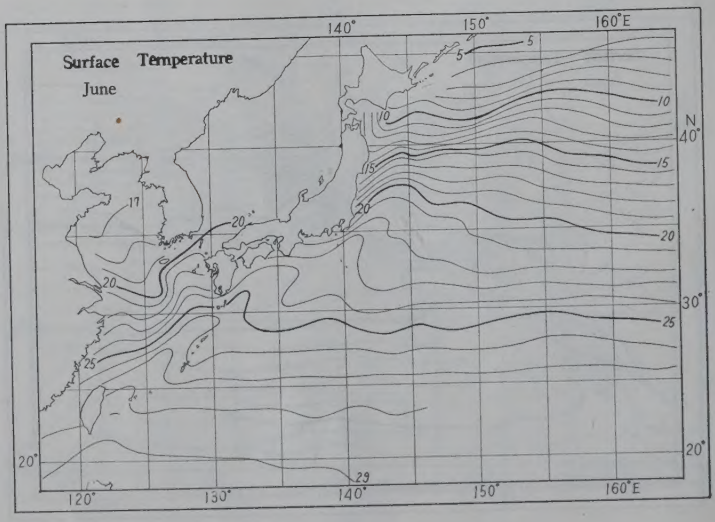

Surface Temperature
January
140°
150°
160°E
120°
130°
N
40°
30°
20°
4
5
10
15
20
25
26

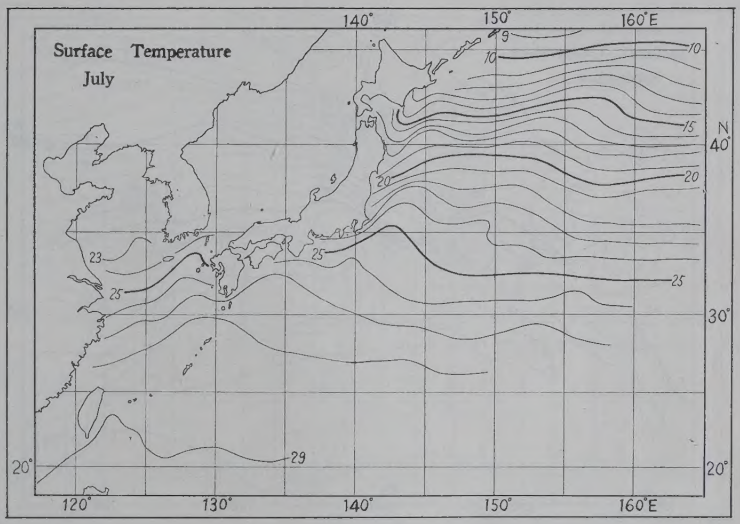

Surface Temperature
February
140°
150°
160°E
120°
130°
N
40°
30°
20°
3
5
10
15
20
25

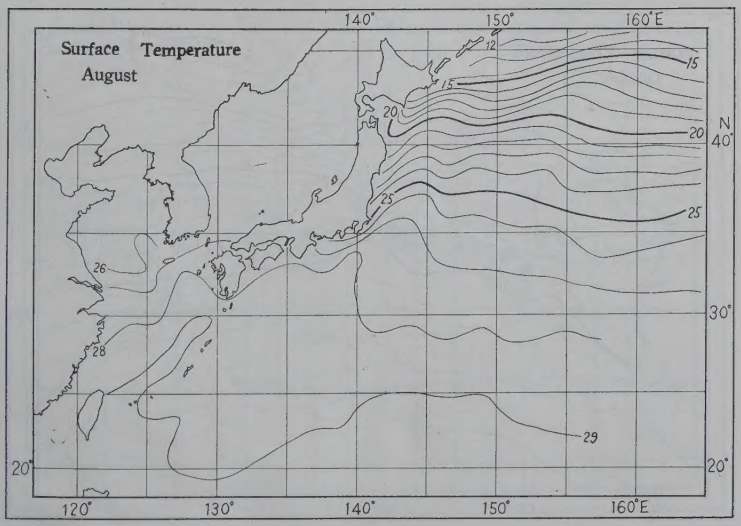

Surface Temperature
March
140°
150°
160°E
N
40°
30°
20°
120°
130°
140°
150°
160°E

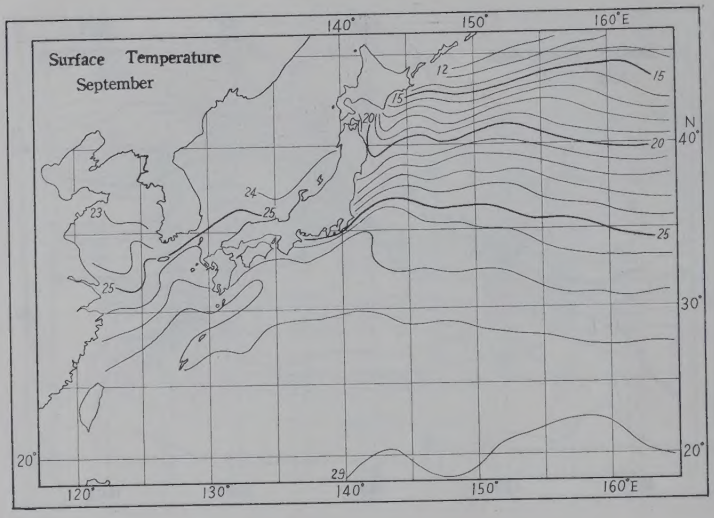

Surface Temperature
April
140°
150°
160°E
N
40°
30°
20°
120°
130°
140°
150°
160°E

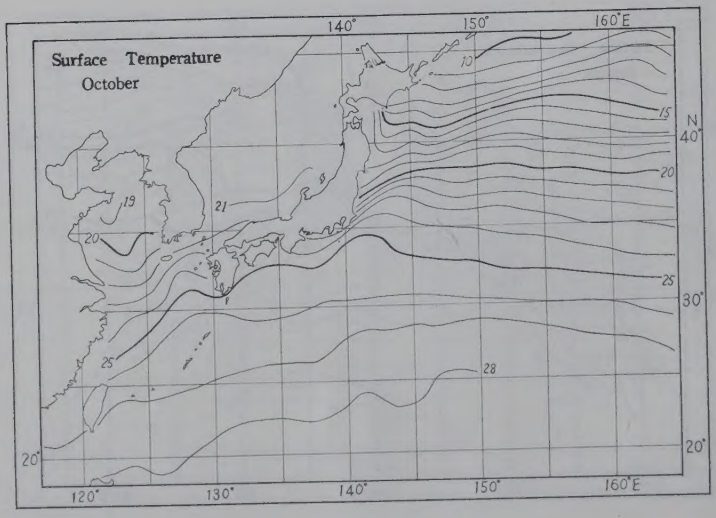

Surface Temperature
May
140°
150°
160°E
N
40°
30°
20°
120°
130°
140°
150°
160°E
5
3
10
15
20
25
28

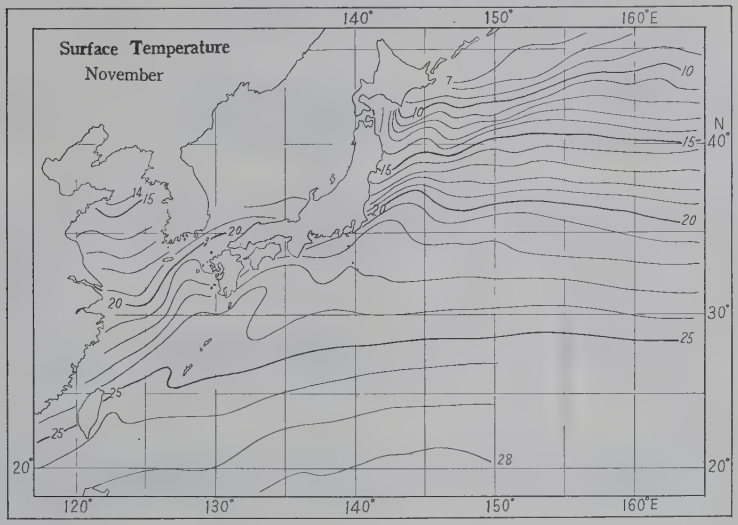

Surface Temperature
June
140°
150°
160°E
N
40°
30°
20°
120°
130°
140°
150°
160°E
5
10
15
20
25
29

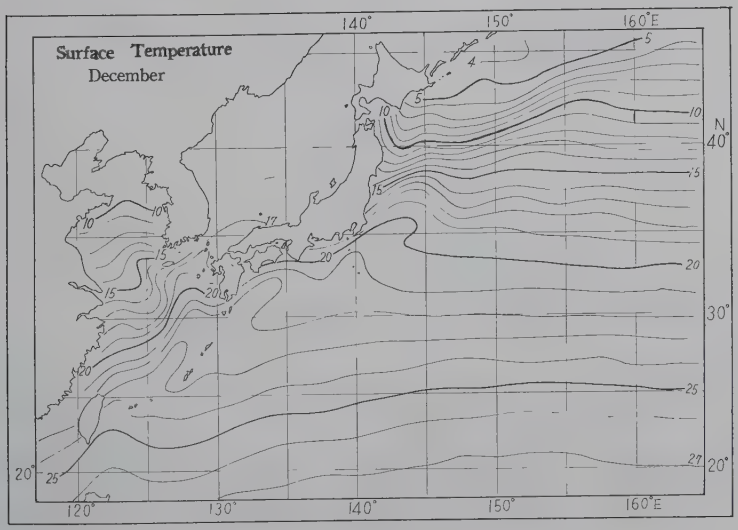

Surface Temperature
July
140°
150°
160°E
N
40°
30°
20°
120°
130°
9
10
15
20
23
25
29

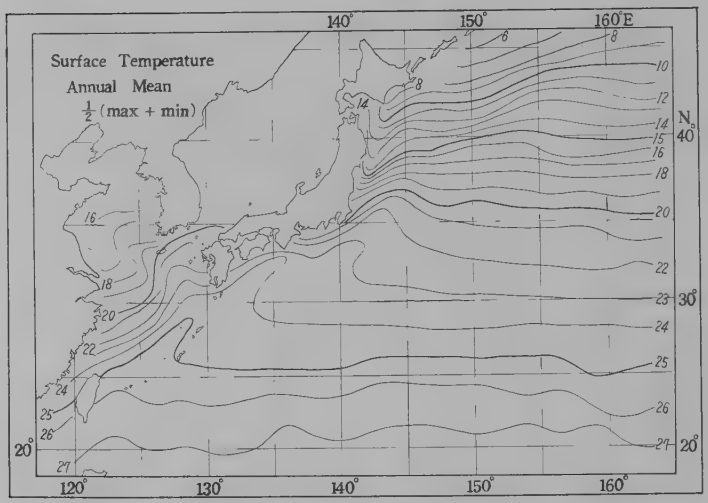

Surface Temperature
August
140°
150°
160°E
N
40°
30°
20°
120°
130°
12
15
20
25
26
28
29

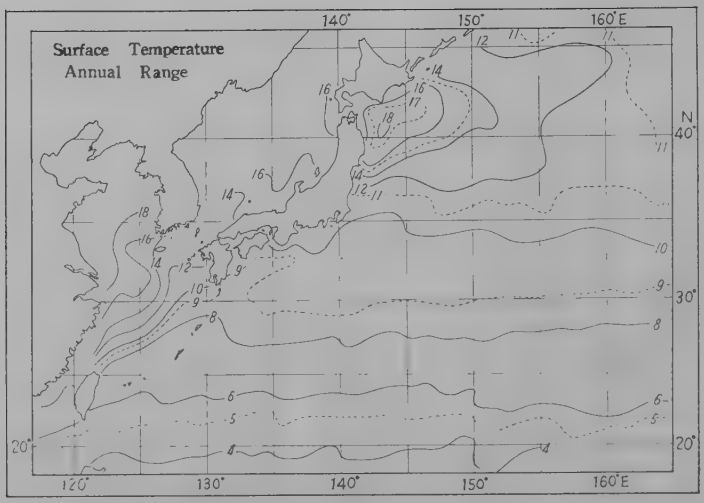

Surface Temperature
September
140°
150°
160°E
120°
130°
140°
150°
160°E
N
40°
30°
20°
20°
12
15
20
25
29
24
23

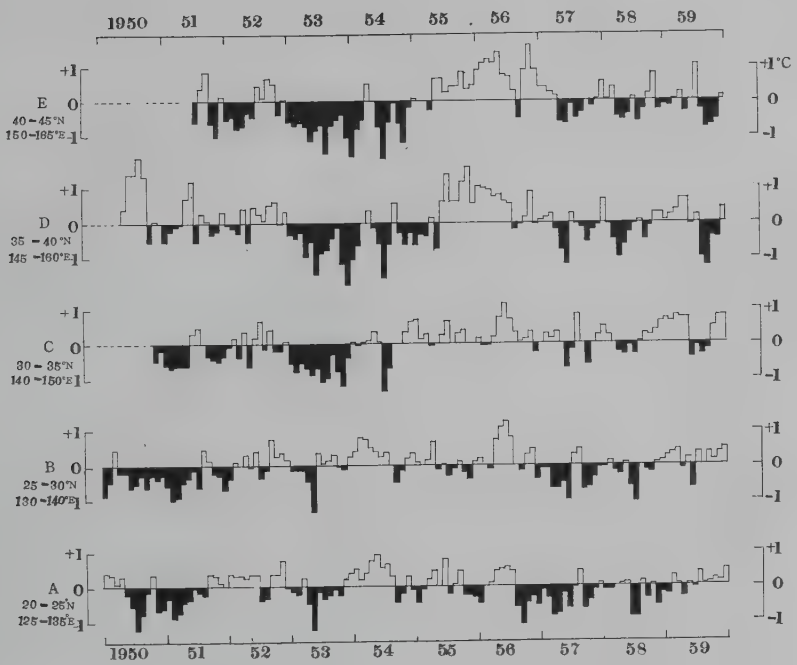

Surface Temperature
October
140°
150°
160°E
120°
130°
140°
150°
160°E
N
40°
30°
20°
20°
10
15
20
25
28
19
21


Surface Temperature
November
140°
150°
160°E
N
40°
30°
20°
120°
130°
140°
150°
160°E


Surface Temperature
December
140°
150°
160°E
N
40°
30°
20°
120°
130°
140°
150°
160°E


Surface Temperature
Annual Mean
$\frac{1}{2}$ (max + min)
140°
150°
160°E
N.
40°
30°
20°
120°
130°
140°
150°
160°


Surface Temperature
Annual Range
140°
150°
160°E
N.
40°
30°
20°
120°
130°
140°
150°
160°E



Chronological anomalies of monthly mean tempera re.

The Oceanographical Magazine
Vol. 13. No. 2, March 1962

The Deep-Current in the Sea East of Japan*, **

By

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Tosio NAN'NITI *Meteorological Research Institute*
Masashi YASUI *Japan Meteorological Agency*

(Received December 21, 1961)

Abstract: The deep-current in the sea east of Japan has been studied by means of the neutral-buoyancy float. The result shows the existence of south-ward currents in waters shallower than 3,000 m in this area. The tidal effect on deep-current and the energy dissipation in the mean current are also dealt with in this paper.

1. *Introduction*

As we know, there are many techniques to measure the current in deep layer in the open ocean. The authors suppose that the most effective one would be the tracking of the neutral-buoyancy float, which was invented by SWALLOW (1955 and 1957).

Construction of Swallow-type instruments was proceeded in Meteorological Research Institute, and one of the authors (TAKENOUTI, 1961) was able to complete them at the end of the year 1959. In manufacturing, some parts of the apparatus were modified in a little different type from the original one in order to avoid difficulties in obtaining them in Japan. Neverthless, we could produce the apparatus having almost the same characters as that made by SWALLOW, with the exception of the following two points; namely the measurable range from the ship is a little larger, whereas the life of the float is a little shorter than the original.

In this paper we would like to report the results of the measurements of deep-currents in the sea east of Japan, by means of the neutral-buoyancy float.

---

* Presented at the TENTH PACIFIC SCIENCE CONGRESS, held at the University of Hawaii, Honolulu, Hawaii, U.S.A., 21 Aug. to 6 Sept., 1961, and sponsored by the National Academy of Sciences, Bernice Pauahi Bishop Museum, and the University of Hawaii.

** JEDS Contribution No. 28.

*** Present adress; Office of Oceanography, UNESCO.

2. *Operations*

The operation has been made twice; once in early September, 1960 in the neighbourhood of 39° 30′N, 145°E and for the second time in May, 1961 in an area a little south-west of the first area (Fig. 1).

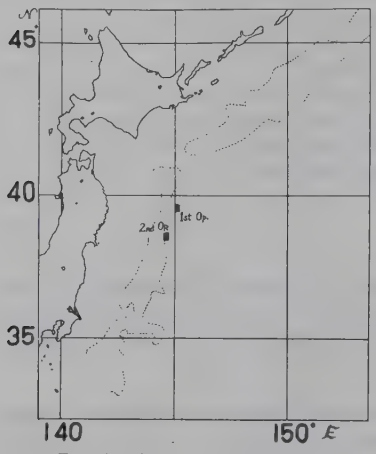

Fig. 1. Areas of operation.

In this region, an accuracy of Loran seems to be about ±0.5 nautical miles in the absolute values. It is, however, conceivable that the relative position of successive reckonings would have an accuracy much better than this value. Examining the results of the first operation, we concluded that the accuracy of the ship's position obtained by Loran is better than that which is required for the purpose, provided the float drifted more than a mile in the whole interval of observation. Therefore, the entire operation was carried out without mooring buoy.

In the first operation, weights of the two floats were adjusted to be submerged and drifted in the water of 1,500 m and 2,500 m depths respectively.

Both of these floats were lost within a day after launching, while the float could emit the pulse signals over 3 days in the laboratory. The causes of this shortness of life of the float were extensively discussed. The air temperature of this period is considerably higher than that of the deep sea water. When the float sank into deep water, the case of the float got cooler, and the humidity in the case became gradually higher and higher and finally it must have reached saturation. This high humidity is considered to bring about some bad effects upon the electronic parts. Therefore, in constructing the floats for the second operation much care was taken to make them moisture-proof.

In the second operation, three floats were released into two layers; two at 1,000 m depth and one at 3,000 m depth. At 1,000 m depth, the current

seemed to be fairly fast, though the accuracy of the measurements was not so good. However, the fastnes was ascertained by the following float at the same depth. The velocity was as great as about one knot and we ceased to track floats in about 13 hours. At 3,000 m depth, however, the current seemed be to very slow and we could obtain satisfactory data by tracking the float over 60 hours.

3. Results of measurements

The results of the first operation are summarized in Fig. 2 and 3. The positions of the float are shown in rectangular representation considering the

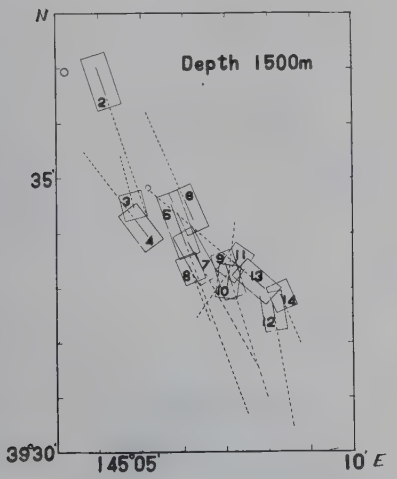

Fig. 2. Trajectory of float.
(1,500m, Sept., 1960)

2: 11h50m
3: 12 36
4: 15 23
5: 17 11
6: 19 10
7: 21 13
8: 21 53
9: 23 48
10: 01 06
11: 01 52
12: 03 22
13: 04 47
14: 06 50

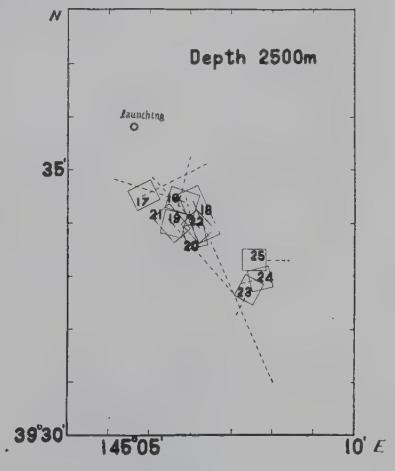

Fig. 3. Trajectory of float.
(2,500m, Sept., 1960)

15: 20h03m
16: 21 01
17: 21 47
18: 00 10
19: 01 25
20: 03 34
21: 05 07
22: 06 23
23: 12 11
24: 13 59
25: 16 47

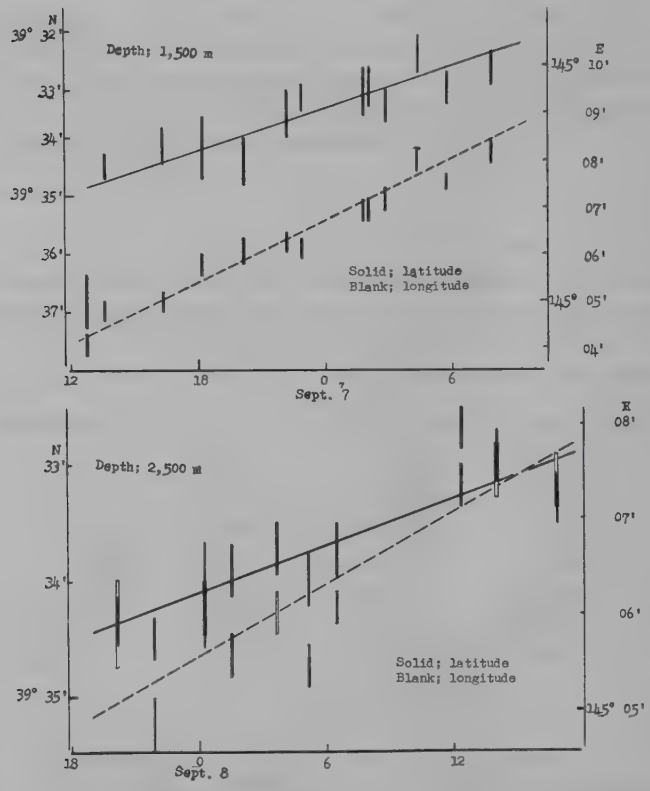

Fig. 4. Time lapse of locations of floats.

errors of measurement and ship's positions. The ship's positions of each measurements are shown with the end points of the broken lines drawn from centers of each rectangle.

The movements in the north and the east components with the lapse of the time are shown in Fig. 4 on the time-latitude or -longitude plane. From these data, we can obtain the mean velocities by means of the least square method as follows: At 1,500 m depth, the float must have drifted in the direction of 124° with the speed of 11 cm/sec and at 2,500 m depth, in the

direction 130° with the speed of 6.7 cm/sec.

The magnitude 6.7 cm/sec is so large that one may raise the question whether the float actually drifted in the layer as deep as 2,500 m. In Fig. 3., almost all parts of two rectangles obtained by the measurements, which were taken in rather short period, are overlapping each other. We may be able to regard this fact as evidence for the preciseness of measurement. This fact may also be the evidence for the correctness of the estimated depth of the float. We may thus be sure of the drift in the layer of nearly 2,500 m depth.

About ten days before our operation, many oceanographical stations were occupied by R/V Ryofu-Maru and hydrographical casts were taken in the same area. The results of these observations (J. M. A., 1961) shows the existence of a semi-isolated warm water with a strong clockwise eddy. The center of this eddy was found to be at 39.5° N, 144.5° E at the surface (Fig. 5). The area, in which the float was launched, might be in the southward current region of the eddy. Therefore, it seems to be rather doubtful that the general current in this region is always as fast as 6.7 cm/sec in the layer more than 2,000 m depth.

The results of the second operation are summarized in Fig. 6 and 7. In

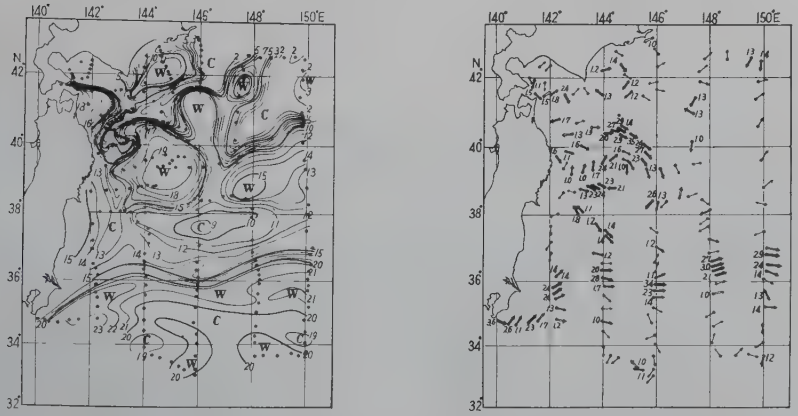

Fig. 5. Oceanographical conditions in Aug. to Sept., 1960.
Left: temperature (100m). Right: surface current.

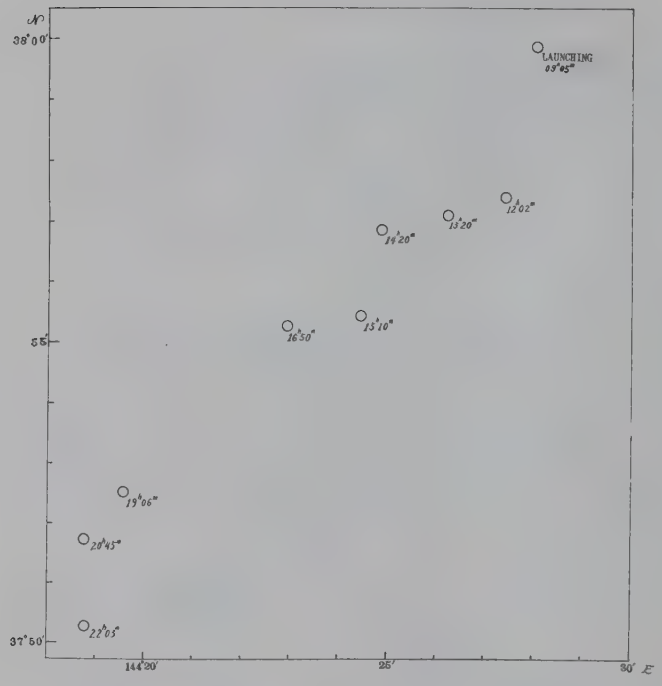

Fig. 6. Trajectory of float in 1,000 m water.

these figures, positions of the floats are represented in points, because representation of uncertainty for every positions seems to be unnecessary. The relationships between the time and the latitude or longitude of floats are shown in Fig. 8. From these, the mean velocities were computed by the least square method as follows; 55.4 cm/sec in the direction 223° in 1,000 m depth and 1.4 cm/sec in the direction of 219° in 3,000 m depth.

In this operation, we made hydrographical casts to 4,000 m depth at four corners of the square enclosing the area of the deep-current measurement. We also measured the surface current continuously along four sides of this square by means of G. E. K.. Masuzawa (1961) computed dynamicaly the current profile referred to the mean surface current.

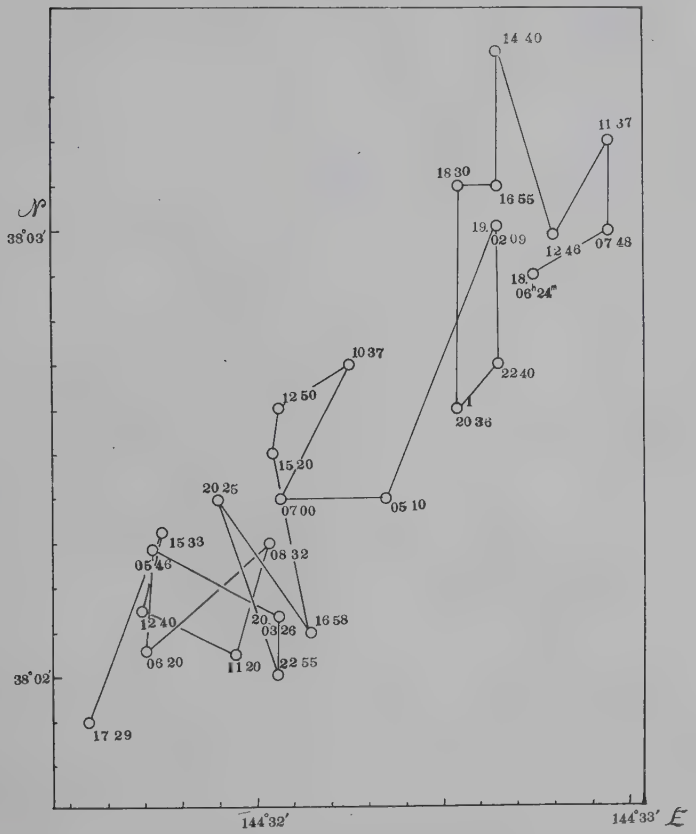

Fig. 7. Trajectory of float in 3,000 m water.

Indeed, we were a little surprised by the magnitude 55.4 cm/sec in the results of our measurements. According to MASUZAWA, the difference between the north-south components of the currents in water of 1,000 m and 3,000 m depths is about 35 cm/sec, while the difference between them derived from our results is about 40 cm/sec. These values are of the same order (Fig. 9).

MASUZAWA's dynamic computation referred to the mean surface current shows the southward current in the upper 1,930 m layer and the northward current in waters deeper than this depth. Causes of these discrepancies

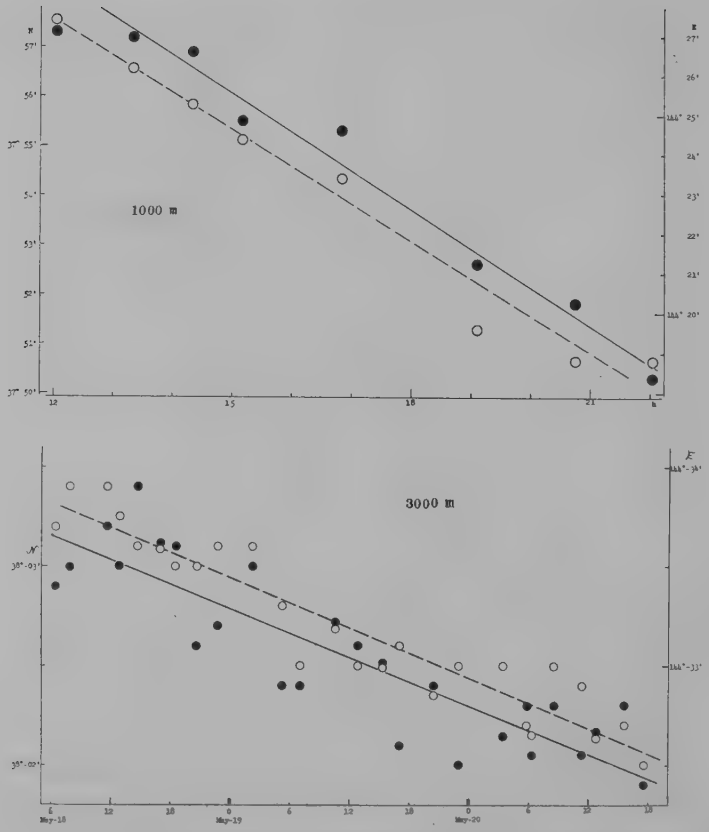

Fig. 8. Time rate of movement of the float in north and east component.
Upper; 1,000 m depth. Lower; 3,000 m depth.
●; latitude. ○; longitude.

between the results of the computations and our measurements have not sufficiently been discussed yet. However, one of the authors points out that the discrepancies may be due to regarding the results of G. E. K. measurements as directly representing the surface current itself.

Any way, we observed two times the southward current in the different

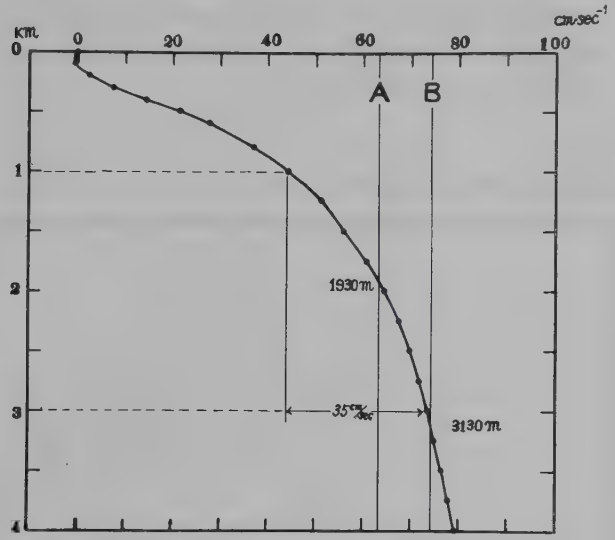

Fig. 9. Average N–S component of geostrophic velocity across Sec. 1501~1502 and Sec. 1503~1504.
A: Referred to average surface velocity.
B: Referred to 3,000 m velocity.

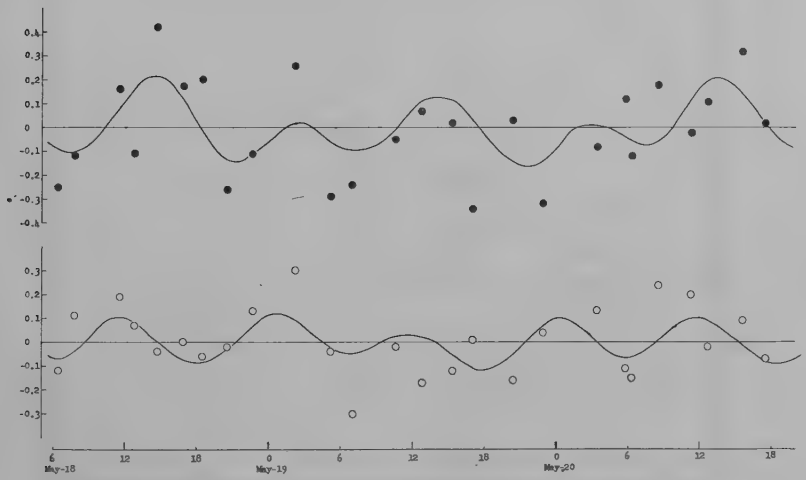

Fig. 10. Deviation of locations of the float from the mean current.
Upper; north component. Lower; east component.

periods in almost the same region. So, we may be able to conclude that the subsurface current in less than 3,000 m depth flows southwards and not northward as suggested by some people.

4. Tidal effect

Watching the rambling of floats, the authors raised in their minds the

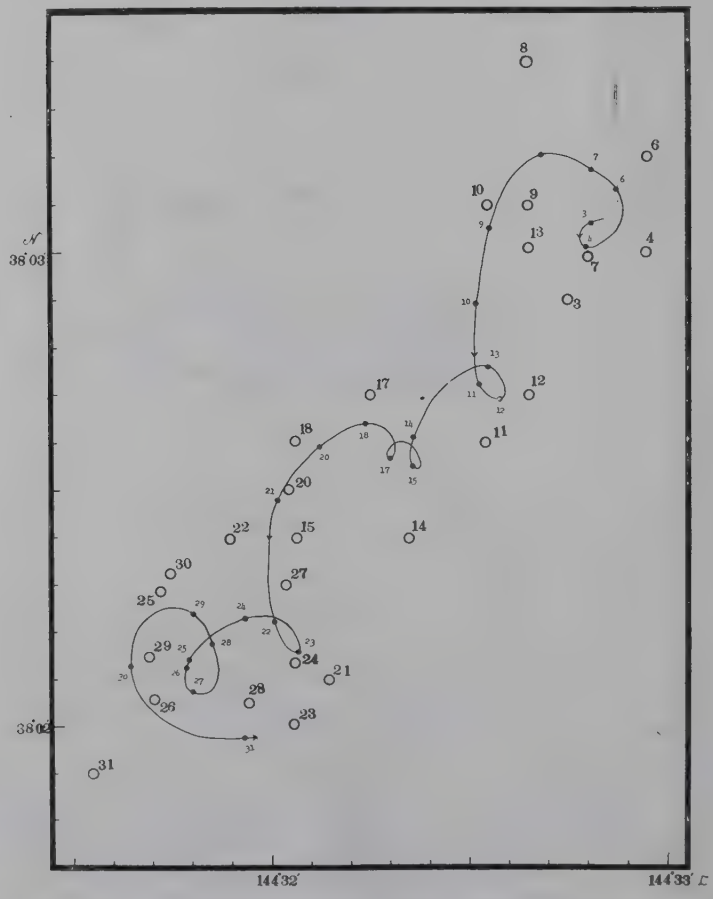

Fig. 11. Computed trajectory of water particle (3,000 m).

effects of tidal currents. However, periods of measurements were too short to analyze the tidal effects statistically, with the exception of the case for 3,000 m depth in May, 1961. Fig. 10, shows deviations of the float from the mean current in the latitude and longitude. In this figure, the movements with tidal periods seems to exist. The harmonic analyses for diurnal and semidiurnal periods are computed from these data and the results of the computation are also shown in the same figure. The resultant curves are fairly well fitted on the observed results (Fig. 11).

The probability, with which these diurnal and semidiurnal periodicity are expected to be obtained from random data (YASUI, 1961) was also computed. The magnitude of this probability are about 0.35 for diurnal period and 0.10 for semidiurnal period. These values are not very small. However, the largeness of these probabilities must partly be due to the shortness of the observation period, because the whole interval of the observation was only twice the diurnal period or a little longer. For instance, the probability for the diurnal period can not be less than about one seventh in our case, even if the fluctuation is of ideal harmonic motion. Considering the effect of the shortness of the observation periods, the existence of the tidal current in such deep layer as 3,000 m depth seems to be fairly probable.

5. *The energy dissipation in the mean current*

The energy dissipation in the ocean current is extensively studied by many authors. According to them, the mass rate of energy dissipation is approximately given by the following expression:

$$\frac{dE}{dt}=K(dV/dz)^2\,,$$

where E, t, K, V and z are energy, time, vertical eddy viscosity, current velocity and depth respectively.

If we assume that the vertical current profile could be represented in the exponential formula, we would obtain the following expression for the mean current profile in the period of the second operation (Fig. 12):

$$V(kt)=1.8\times e^{-1.1\times10^{-3}z\,(m)}$$

If we assume that the magnitude of the vertical eddy viscosity is 100 cm^2/sec at 500 m depth, then we obtain $3.3\times10^{-5}\,cm^2/sec^3$ as the magnitude of

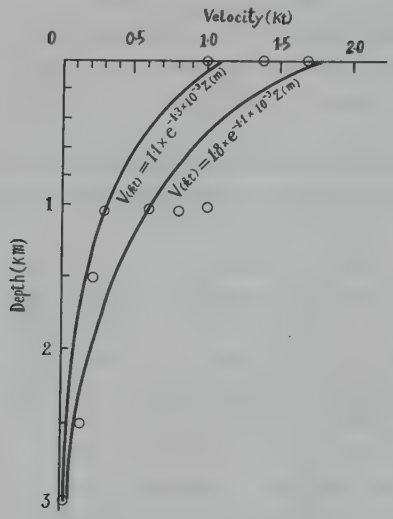

Fig. 12. Current profiles estimated from data of tracking the buoy.

the mass rate of the energy dissipation at the same depth. The order of this magnitude is quite the same as the value of the energy dissipation presented by many authors.

Acknowledgement: The authors wish to express best thanks to Dr. J. C. SWALLOW, who sent us much information in the stage of programming the construction of the instruments. Thanks are also due to Dr. S. UYEDA of the Earthquake Research Institute for reading the manuscript. They also indebted to Mr. H. AKAMATSU and the other members of the JEDS-4 for their kind cooperation aboard the ship.

References

MASUZAWA, J., (1961): Deep-water circulation in the western boundary of the north Pacific. Presented at the tenth Pacific Science Congress. (to be published).

SWALLOW, J., C., (1955): A neutral-buoyancy float for measuring deep currents. *Deep-Sea Research*, **3**, 1955.

——, (1957): Some further deep current measurements using neutrally-buoyant floats, *Deep-Sea Research*, **4**, 1957.

TAKENOUTI, Y., (1961): Deep-current measurements by means of the neutral buoyancy float. *Oki Review*, **28** (2), 1961 (in Japanese).

YASUI, M., (1961): Internal waves in the open ocean—Internal waves of long periods in the ocean weather station "Tango". *Oceanogr. Magaz.*, **12** (2), 1961.

The Oceanographical Magazine
Vol. 13. No. 2, March 1962

Theoretical Investigations of Typhoon Surges along the Japanese Coast (II)

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(Received January 8, 1961)

Chapter 4. Rotational cases

4.1. Modifications for the non-rotational theory

In Chapter 3, we treated the non-rotational cases where the effects of earth's rotation are neglected. These cases are nearly applicable to storm surges in small basins, but not to those in large basins in which Coriolis terms become important. In the following, we shall treat such cases.

The equations of motion and continuity will become

$$\left.\begin{aligned} &\frac{\partial u}{\partial t}-fv+g\frac{\partial}{\partial x}(\zeta-\zeta_0)-\nu\frac{\partial^2 u}{\partial z^2}=0\,,\\ &\frac{\partial v}{\partial t}+fu+g\frac{\partial}{\partial y}(\zeta-\zeta_0)-\nu\frac{\partial^2 v}{\partial z^2}=0\,,\\ &\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0\,, \end{aligned}\right\} \tag{4.1}$$

instead of (3.1), if we disregard the non-linear terms. In (4.1), $f=2\omega\sin\varphi$ denotes the Coriolis parameter, where ω is the angular velocity of the earth's rotation, and φ is the latitude.

The equation (3.4) will be then rewritten as follows.

$$\left.\begin{aligned} &\frac{\partial S_x}{\partial t}=f\cdot S_y-g\cdot h\frac{\partial}{\partial x}(\zeta-\zeta_0)+\tau_s^{(x)}-\tau_b^{(x)}\,,\\ &\frac{\partial S_y}{\partial t}=-f\cdot S_x-g\cdot h\frac{\partial}{\partial y}(\zeta-\zeta_0)+\tau_s^{(y)}-\tau_b^{(y)}\,,\\ &\frac{\partial \zeta}{\partial t}=-\frac{\partial S_x}{\partial x}-\frac{\partial S_y}{\partial y}\,, \end{aligned}\right\} \tag{4.2}$$

where the notation is as mentioned above. (4.2) are well-known equations of

forced long waves on the rotating earth under the existence of the bottom friction. It is shown from them that Coriolis terms predominate for the phenomena in the large horizontal scale, where the travel time of long waves is comparable to or larger than the period of earth's rotation.

According to this rule, Coriolis terms will be more effective in smaller depths provided that the horizontal scale is given. However, this rule holds for depths at least tens of meters. In more shallow seas, the effect of the bottom friction often overcomes that of the Coriolis force. In general cases of surge computations, it will be better to take both effects into account.

The boundary conditions will be not altered by the existence of the rotational effects. From another view-point, we shall slightly modify the bottom condition by introducing more recent results. In Chapter 3, we assumed that the bottom friction is proportional to the current velocity, but this law is not sufficiently rational.

We now assume that the velocity is represented as the quadratic formula with respect to the depth. Putting $\nu=\nu_s$ at the surface, and $\nu=\nu_b$ at the bottom, we easily obtain the extended Yamada's formula

$$\tau_b=\frac{3\nu_b\rho_w}{h}\boldsymbol{V}-\frac{\tau_s}{2}\frac{\nu_b}{\nu_s}. \tag{4.3}$$

It is also shown that

$$\tau_b=\gamma_b^2\rho_w\boldsymbol{V}|\boldsymbol{V}| \tag{4.4}$$

in the absence of the surface stress. From (4.3) and (4.4), we may put

$$\nu_s=\frac{h\gamma_s^2}{3}|\boldsymbol{V}|\ ,\quad \nu_b=\frac{h\gamma_b^2}{3}|\boldsymbol{V}|\ . \tag{4.5}$$

(4.3) then becomes

$$\tau_b=\gamma_b^2\rho_w\boldsymbol{V}|\boldsymbol{V}|-\frac{\tau_s}{2}\left(\frac{\gamma_b}{\gamma_s}\right)^2=\alpha\cdot\boldsymbol{V}|\boldsymbol{V}|-\beta\cdot\tau_s\ . \tag{4.6}$$

(4.6) is similar to Reid's formula (3.7) for smaller winds, and is applicable to general cases approximately. Of course, there remain some questions. The quadratic velocity-profile law is the basic assumption for our formula, and this law will be not always the sufficient representation of the actual profile. However, it will be still said that (4.6) will be used as a better estimate of the bottom stress than the previous one.

4.2. Programing

We have replaced the derivatives in equations (4.2) with central differences in order to solve the hydrodynamic equations numerically by the primitive

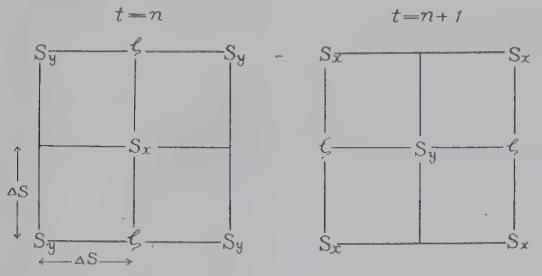

Fig. 4.1. Arrangement of mesh points.

method. The mesh points are now arranged as Fig. 4.1. At the n-th time step, they are arranged as the left-hand figure, and at the next step as the right-hand one. At the $(n+2)$-th step, the arrangement is similar to that at the n-th step, and so on. The water depths are given at the S_x and S_y points.

For above mesh points, the following equations are to be computed:

$$\left.\begin{aligned}
&S_x'(x, y, t+2\Delta t)=a(x, y)S_x'(x, y, t)-b(x, y)\times\{\zeta(x+\Delta S, y, t+\Delta t)-\\
&\quad-\zeta(x-\Delta S, y, t+\Delta t)-\zeta_0(x+\Delta S, y, t+\Delta t)+\zeta_0(x-\Delta S, y, t+\Delta t)\}+\\
&\quad+W_x'(x, y, t+\Delta t)+f\cdot S_y'(x, y, t+\Delta t)\,,\\
&S_y'(x, y, t+2\Delta t)=a(x, y)S_y'(x, y, t)-b(x, y)\times\{\zeta(x, y+\Delta S, t+\Delta t)-\\
&\quad-\zeta(x, y-\Delta S, t+\Delta t)-\zeta_0(x, y+\Delta S, t+\Delta t)+\zeta_0(x, y-\Delta S, t+\Delta t)\}+\\
&\quad+W_y'(x, y, t+\Delta t)-fS_x'(x, y, t+\Delta t)\,,\\
&\zeta(x, y, t+3\Delta t)=\zeta(x, y, t+\Delta t)-S_x'(x+\Delta S, y, t+2\Delta t)+\\
&\quad+S_x'(x-\Delta S, y, t+2\Delta t)-S_y'(x, y+\Delta S, t+2\Delta t)+S_y'(x, y-\Delta S, t+2\Delta t)\,,
\end{aligned}\right\}\tag{4.7}$$

where

$$S_x'=S_x\cdot\frac{\Delta t}{\Delta S}\,,\qquad S_y'=S_y\cdot\frac{\Delta t}{\Delta S}\,,\tag{4.8}$$

and Δt, ΔS are time and mesh intervals, respectively.

Variables $a(x, y)$ and $b(x, y)$ in (4.7) are given by

$$\left.\begin{aligned}
&a(x, y)=\left[1-\frac{\alpha\Delta S}{2}\,\mathrm{Amp}\,\{S_x'(x, y, t_i), S_y'(x, y, t_i)\}\right]\Big/D(x, y, t_i)\,,\\
&b(x, y)=g\cdot h(x, y)\left(\frac{\Delta t}{\Delta S}\right)^2\Big/D(x, y, t_i)\,,\\
&D(x, y, t_i)=1+\frac{\alpha\Delta S}{2}\,\mathrm{Amp}\,\{S_x'(x, y, t_i), S_y'(x, y, t_i)\}\,,
\end{aligned}\right\}\tag{4.9}$$

where t_i means the last time step before ζ_0 and τ_s are given. Since the last quantities are renewed at every 10 minutes step, two variables $a(x, y)$ and

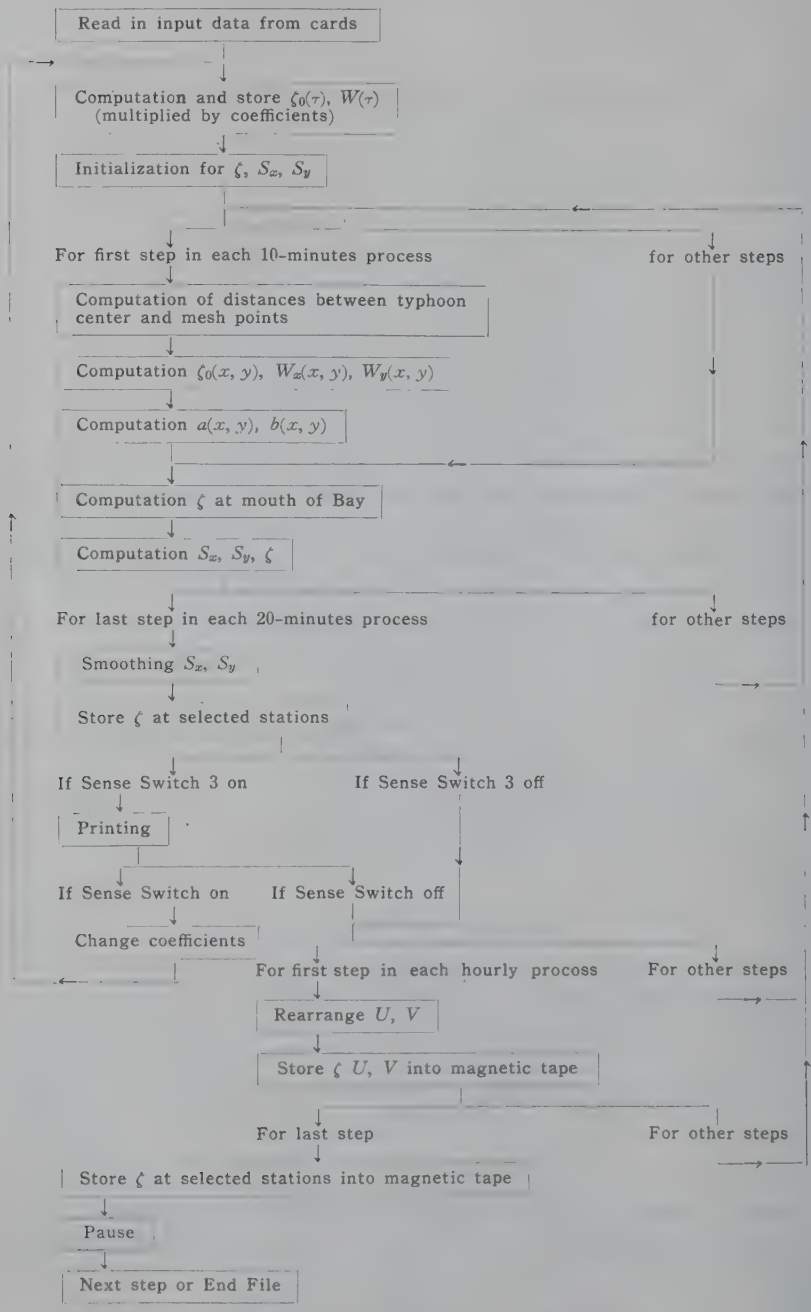
Read in input data from cards
Computation and store $\zeta_0(\tau)$, $W(\tau)$ (multiplied by coefficients)
Initialization for ζ, S_x, S_y
For first step in each 10-minutes process
for other steps
Computation of distances between typhoon center and mesh points
Computation $\zeta_0(x, y)$, $W_x(x, y)$, $W_y(x, y)$
Computation $a(x, y)$, $b(x, y)$
Computation ζ at mouth of Bay
Computation S_x, S_y, ζ
For last step in each 20-minutes process
for other steps
Smoothing S_x, S_y
Store ζ at selected stations
If Sense Switch 3 on
If Sense Switch 3 off
Printing
If Sense Switch on
If Sense Switch off
Change coefficients
For first step in each hourly procoss
For other steps
Rearrange U, V
Store ζ U, V into magnetic tape
For last step
For other steps
Store ζ at selected stations into magnetic tape
Pause
Next step or End File

Fig. 4.2 The second program for Osaka Bay

$b(x, y)$ are also renewed at the same rate.

$W_x'(x, y, t+\Delta t)$, $W_y'(x, y, t+\Delta t)$ are also given by

$$\left.\begin{aligned} W_x'(x, y, t+\Delta t) &= \left(1+\frac{\beta}{2}\right)\frac{(\Delta t)^2}{\Delta S}\tau_s^{(x)}(x, y, t+\Delta t)/D(x, y, t_t)\,, \\ W_y'(x, y, t+\Delta t) &= \left(1+\frac{\beta}{2}\right)\frac{(\Delta t)^2}{\Delta S}\tau_s^{(y)}(x, y, t+\Delta t)/D(x, y, t_t)\,. \end{aligned}\right\} \tag{4.10}$$

We now put

$$\left.\begin{aligned} \alpha &= 2.6\times 10^{-3}\,, \\ \beta &= 0.25\sim 0.50\,, \end{aligned}\right\} \tag{4.11}$$

for two constants in (4.6). The α-value is given after HANSEN (1956), and is equal to that of the surface stress. The β-values are given by actual trials.

Main procedures of our program is shown in Fig. 4.2. In this program, mouth conditions are very important. They are given by the following method:

(i) First, we made the computations for wide area including the basin under consideration with rough meshes, where we put $\zeta=\zeta_0$ at the off-shore side. The off-shore side in this case is taken as offward as possible.

(ii) The ζ-values at the mouth of the basin are given by this first step computations, and they are used as boundary values for the fine mesh computations in the small area.

In the cases of Osaka Bay, we first consider the wide area including Osaka Bay, Harima Nada, and Kii Channel (see Fig. 4.3.). In this wide-area computation, we disregard the bottom friction. It is shown from previous results that the maximum surges are well demonstrated in the absence of the bottom friction, although the seiches become more remarkable than actual ones. The bottom friction is at most one tenth or so of the surface stress in the period of strong winds. However, the former will be more important in the period of weaker winds.

The small-area computations are then made by giving ζ-values at Tomogashima Strait and Akashi Strait from the results of wide-area computations. The coefficient β is adjusted by trials so that the maximum surge height at the bay bottom agrees with the wide-area results.

ζ_0, W_x', W_y', a, and b are all renewed at every 10 minutes step. For this purpose, hourly locations of the typhoon center are given by input cards, and intermediate locations are given by the linear interpolation of them. In previous computations, we assumed the uniform typhoon movement, which sometimes gave discrepant representations of wind and pressure patterns. These

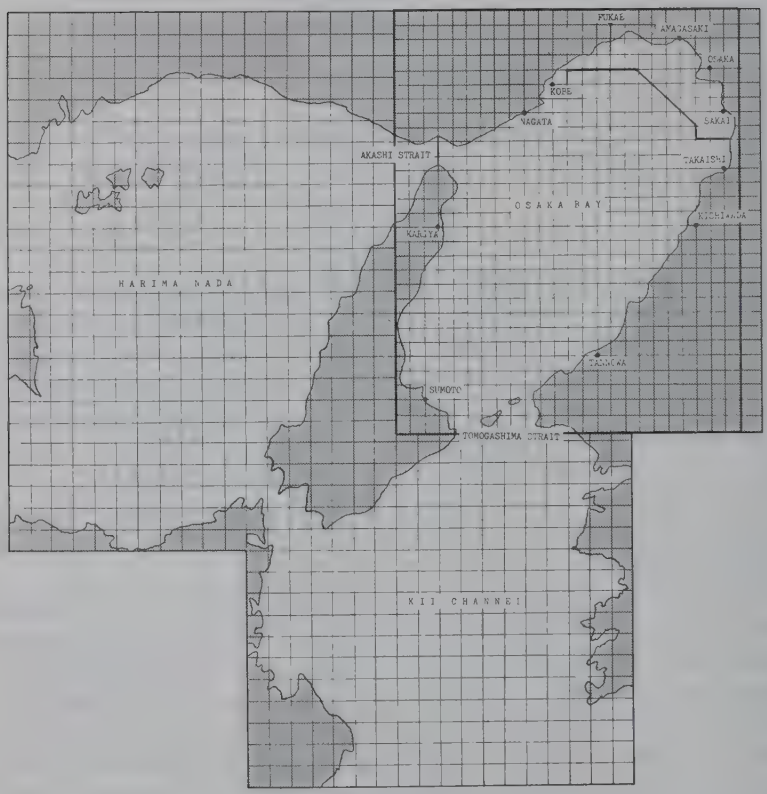

Fig. 4.3. Computed area.

patterns will be better resembled to observations by our new assumptions.

In the second program of Osaka Bay, we make write out the variations of ζ at Osaka by the on-line printer. They are given at every 20 minutes from the epoch to the time step immediately after a selected sense switch is pushed on. The coefficient β can be changed experimentally by the on-line results. If changed, computations are again made from the epoch. If not changed, they are continued from the next step.

4.3. Computations for Osaka Bay

Osaka Bay was three times struck by heavy typhoon surges. They were

induced by the Muroto Typhoon in 1934, the Jane Typhoon in 1950, and the Second Muroto Typhoon in 1961, respectively. Those induced by the Muroto Typhoon were most destructive among them, and the maximumsurge was about 3.1 m higher than normal at Osaka at that time.

We have treated former two cases here. The case of the Second Muroto Typhoon will be also very important, but we did not compute this case since the data were not sufficiently compiled yet.

We first made computations for the wide area. In the case of the Muroto Typhoon, the maximum computed surges were 2.9 m at Osaka, 2.0 m at Kobe, and 1.0–1.2 m along the coast of Harima Nada, which were in fair agreement with the observed values. However, they were only about 1 m or so along the coast of Kii Channel, which seemed to be fairly smaller than observations. Similar results were also shown in the case of the Jane Typhoon, although values are fairly smaller on the whole.

Results of small-area computations are shown in Fig. 4.4–4.7, where we put $\beta=0.38$. Fig. 4.4 shows computed horizontal patterns of storm surges induced by a model of the Muroto Typhoon, from which we can see rapid changes of surge contours. The horizontal pattern at 9 h shows strong elevations towards north-east, and the highest value is about 2.5 m. The maximum surges in this area will occur near this time.

From Fig. 4.5, we know that the flow first enters from Tomogashima Strait and goes out from Akashi Strait. After maximum surges, the anti-clockwise circulation appears in the southern part and the flow goes out from both mouths. At 13 h, the flow turns to north in the whole area.

In the case of the Jane Typhoon, horizontal patterns fairly resemble to those of the above case (see Fig. 4.6 and 4.7), but surges are generally lower than those.

The highest computed surges are 3.09 m at Amagasaki, 2.93 m at Osaka, 2.68 m at Sakai, and 1.73 m at Kobe respectively for the former case. The corresponding values for the latter case are 2.71 m, 2.67 m, 2.19 m, and 1.33 m, respectively. The values are in good agreement with the observed ones as stated in next paragraph.

4.4. Comparison with the observation

Fig. 4.8 shows the observed and computed variations of storm surges at

Fig. 4.4. Computed horizontal distribution of surges in the case of Typhoon Muroto.

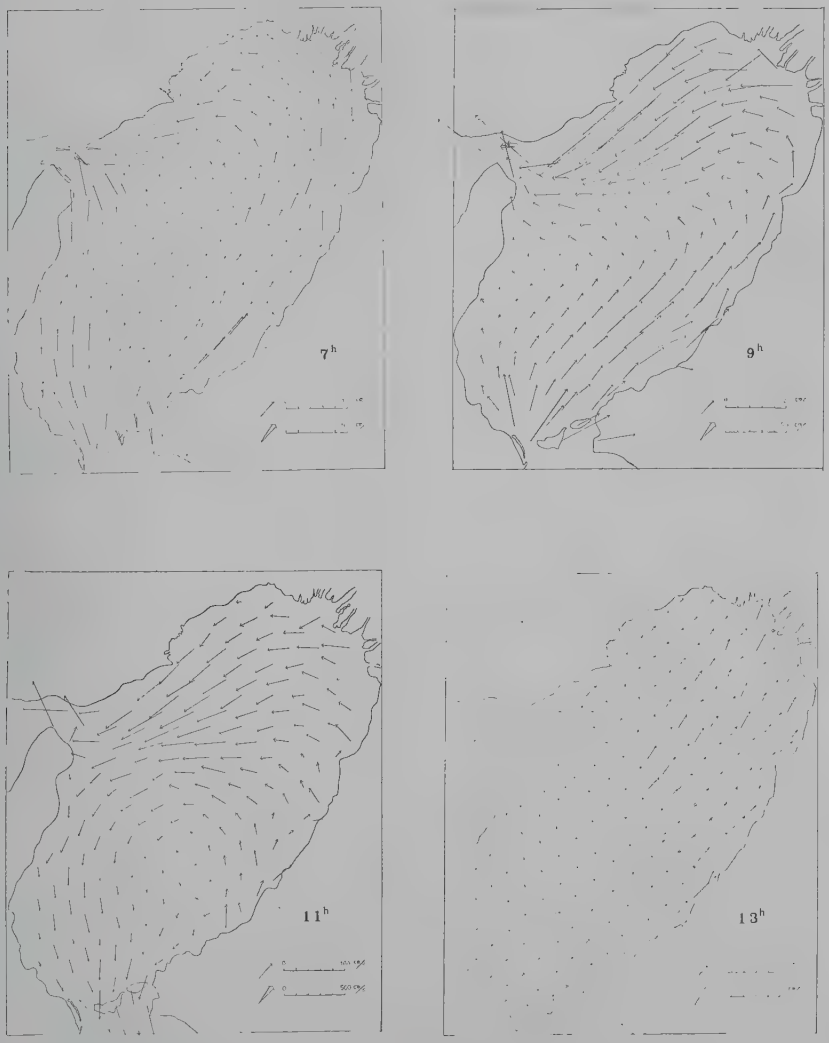

Fig. 4.5. Computed horizontal distribution of the wind driven currents in the case of Typhoon Muroto.

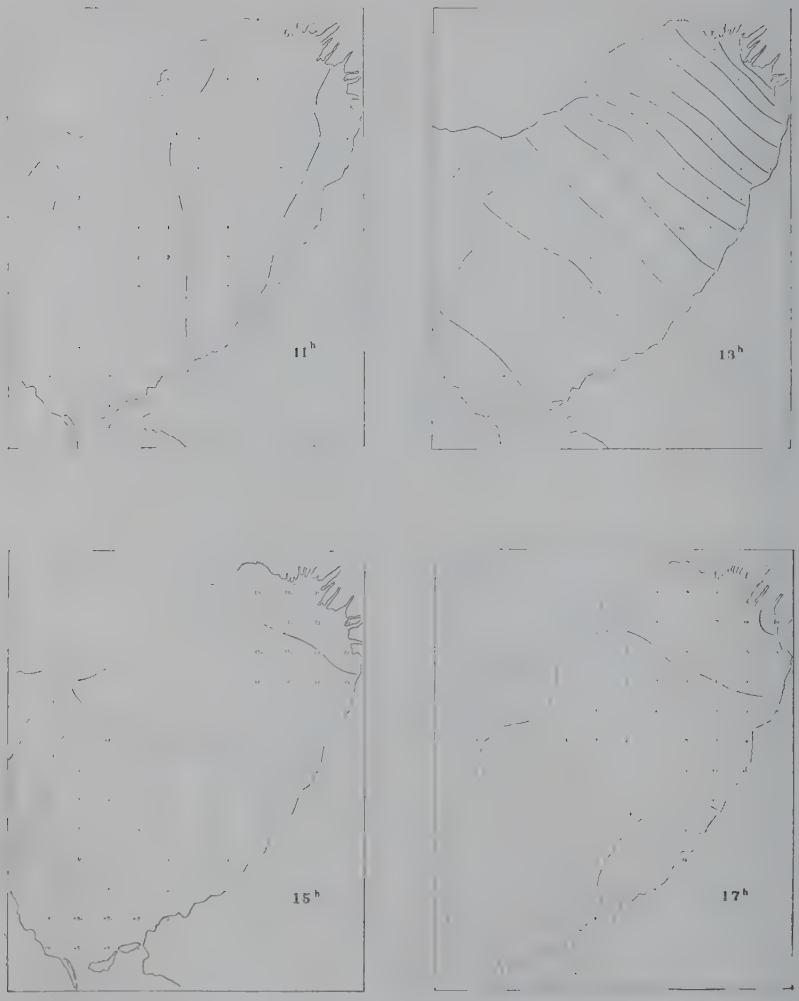

Fig. 4.6. Computed horizontal distribution of surges in the case of Typhoon Jane.

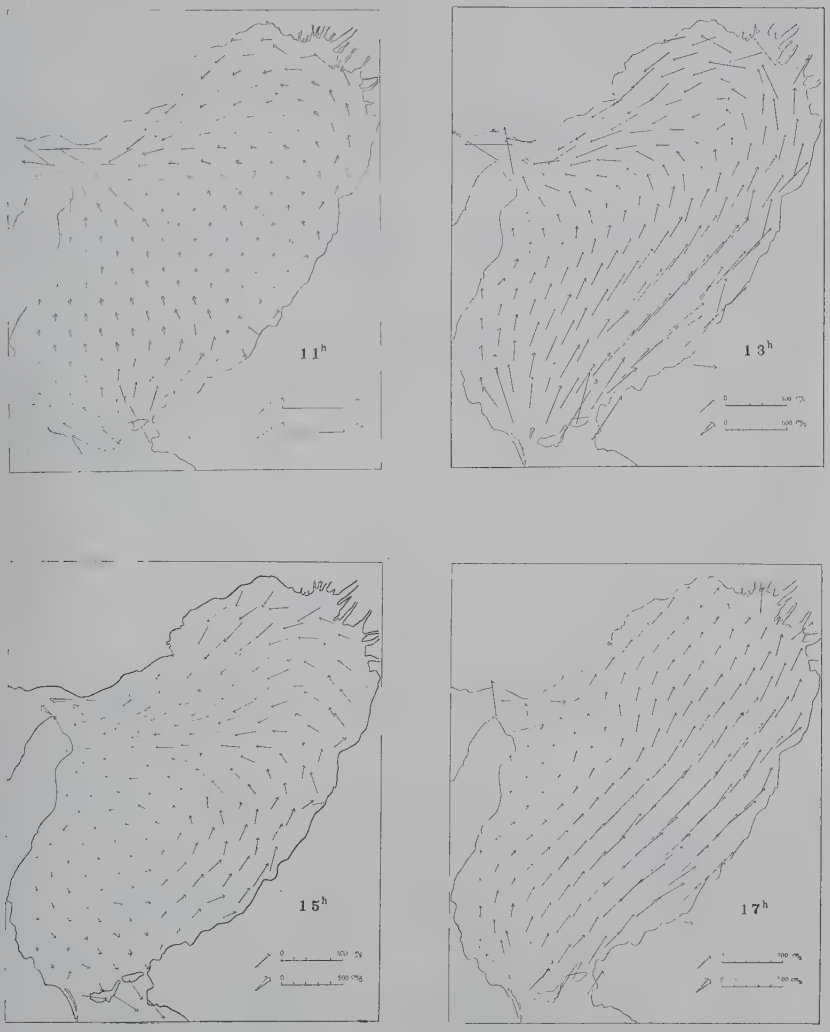

Fig. 4.7. Computed horizontal distribution of the wind driven currents in the case of Typhoon Jane.

four stations, Osaka, Kobe, Kishiwada, and Sumoto in the case of the Jane Typhoon. It is shown from these curves that the computations by the above-stated model (Model S2) are in fair agreement with the observations except for those at Sumoto, where the computed pattern agrees with the observation but the amplitude is only one half the latter. The similar features are also shown in the case of the Muroto Typhoon, but we have only few observations in this case.

We thus try to adjust elevations in Tomogashima Strait to observations by multiplying computed values by the factor 2.0. Elevations in Akashi Strait are left as they are.

The computed results by this modified model (Model S7) are also shown in Fig. 4.8. These new computations are in better agreement with observations. They are analogous not only in general patterns and amplitudes but

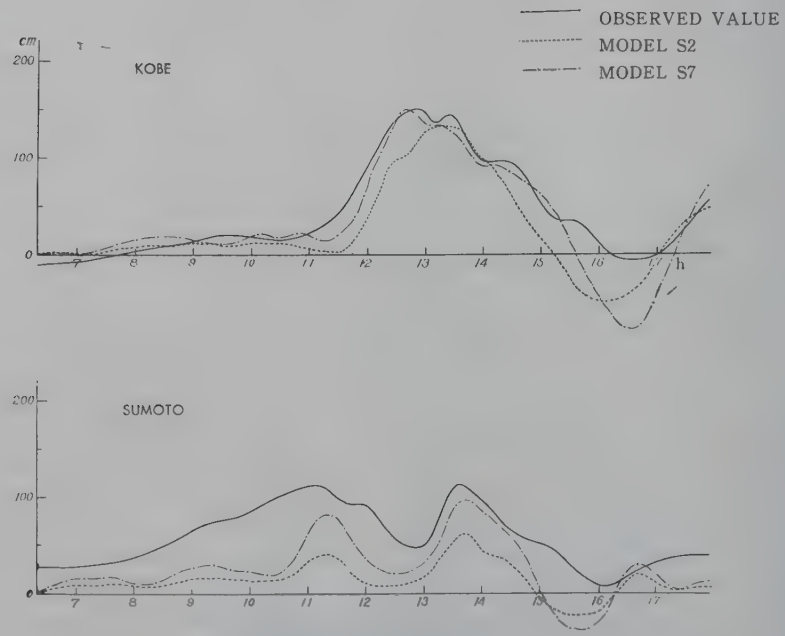

Fig. 4.8a. Observed and computed variatiors of ζ at four stations, Kobe, Sumoto, Kishiwada and Osaka.

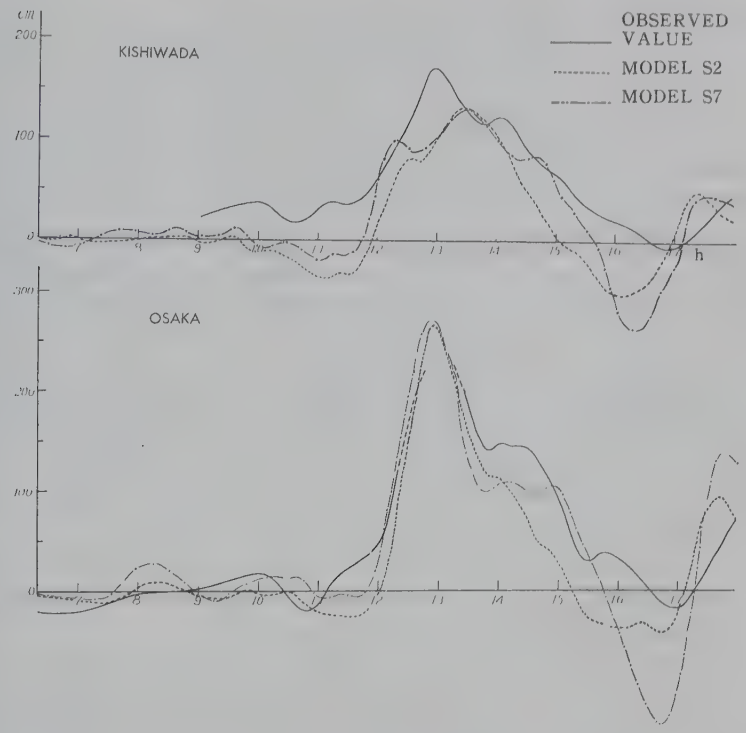

Fig. 4.8b.

also in main characteristics of seiches. From these results, we may conclude that the actual mechanism of the surge generation in the basin will be not so far from our theory. One of the most important questions unsolved will be not so far from our theory. One of the most important questions unsolved will be, undoubtedly, the generation of surges near the mouth of bays or along the straight coast.

Chapter 5. Discussions and remarks

In these chapters, we have expressed the results of theoretical investigations on storm surges. We made use the electronic computer IBM 704 for this purpose, and assumptions were lessened as few as possible. However, questions still occur from these minimum assumptions. We shall point out

these questions in the following.

(i) *The surface wind.* The distribution of the surface wind around the typhoon center is fairly well represented by our second assumption, *i.e.*, that the wind consists of two parts. However, the computed pattern seems to be somewhat weaker than the observed one near the center, and stronger than the latter in distant area. Of course, we have now few data of typhoon winds on the sea, and computations can be only compared with the data on the land. It will be one of our important problems to investigate the radial and angular distributions of typhoon winds on the sea experimentally and quantitatively.

(ii) *The surface wind stress.* The coefficient $\gamma^2=2.6\times10^{-3}$ is questionable. This value has been used rather mechanically. However, according to recent studies, γ^2 seems fairly smaller than 2.6×10^{-3} for weaker winds, and it also depends on the stability of the lower atmosphere and on the wind speed itself. The condition for very strong winds will be first cleared up after the direct observations are carried out.

(iii) *The bottom stress.* The bottom stress will be fairly modified by our last assumption (4.6), but there still remain some questions.

(iv) *The mouth condition.* The computed surges were always lower than observations near the mouth. In the case of Osaka Bay, we extended the computing area, but discrepancies were still left.

The storm surges near the mouth will consist of the direct long waves from typhoon center, their reflections, edge waves propagating along the continental shelf, internal Kelvin waves, etc. We shall thus extend the computing area 200–300 km offward to the ocean in the next chance. The typhoon field will be sufficiently included in this area, although the mesh intervals will be at least 10 km or more. The mouth conditions for the small-area computations will be fairly modified by this attempt.

Acknowledgements: The authors here wish to express their hearty thanks to Dr. K. Terada, Chief of the Marine Division, JMA, who kindly encouraged us and made able to this study. They are also greatly indebted to Dr. K. Yoshida and Dr. K. Kajiura of Tokyo University for their kind advices throughout this work.

References

Fujita, T. (1952): Pressure distributed in typhoon. *Geophys. Mag.*, **23**.
Hansen, W. (1956): Theorie zur Errechung des Wasserstandes und der Stromungen in

Randmeeren nebst Anwendungen. *Tellus*, 8.

Japan Meteorological Agency and Tokyo Metropolitan Government (1960): Numerical investigation on storm surges in Tokyo Bay. 247 pp.

KIVISILD, H. R. (1954): Wind effect on shallow bodies of water with special references to Lake Okeechobee. *Trans. Roy. Inst. Tech. Stockholm*, Bul. 43.

Marine Division, JMA (1960): Investigations on storm surges produced by the Ise Bay Typhoon with some technical conditions. *Tech. Rept. of JMA*, No. 4.

Marine Division, JMA and Third Port and Harbour Const. Bureau, JMT, (1961): Numerical investigations on storm surges in Osaka Bay with some technical conditions. *Tech. Rept. of JMA*, No. 11.

PLATZMAN, G. W. (1958): A numerical computation of the surge on 26 June 1954 on Lake Michigan. *Geophysica*, 6 (3/4)

REID, R. O. (1957): Forced and free surges in a narrow basin of variable depth and width: A numerical approach. *Tech. Rept. Texas A & M Research Foundation*, No. 153.

REID, R. O. (1957): Modification of the quadratic bottom-stress law for turbulent channel flow in the presence of surface wind-stress. *Tech. Mem. Beach Erosion Board* No. 13.

TAKAHASHI, K. (1939): Pressure and wind speed distributions in typhoon. *Kisho Shushi*, **II 17**. (in Japanese)

YAMADA, H. (1950): Theoretical estimation of meteorological high water. *Rept. Res. Inst. Fluid Eng. Kyushu Univ.*, **6** (2).

The Oceanographical Magazine
Vol. 13. No. 2, March 1962

Preliminary Report of the Japanese Expedition of Deep-Sea, the Fourth Cruise, 1961 (JEDS-4)*

By

Jotaro Masuzawa**

INTRODUCTION

The Japanese Expedition of Deep-Sea, the Fourth Cruise (JEDS-4) which had been arranged by the Deep-Sea Research Committee (Chairman, K. Wadati), Japan Society for Promotion of Science, was carried out in the sea east of Japan in May, 10 to 24 and in June, 5 to 30, 1961 on board the research vessel Ryofu-Maru (Captain, T. Suenaga) of the Japan Meteorological Agency. In the former period, the deep-currents were measured at the station E_0 (38°N, 144.5°E) just east of the Japan Trench by the neutrally buoyant float of

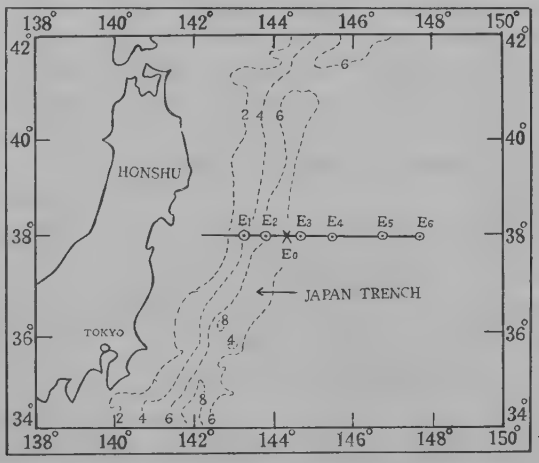

Fig. 1. The observational stations occupied by the Ryofu-Maru in the Japanese Expedition of Deep-Sea, the Fourth Cruise (JEEDS-4) in May to June, 1961. St. E_0: Deep-current measurement. Broken line: Isobath (km).

* JEDS Contribution No. 29.

** Japan Meteorological Agency.

Swallow's type. In the latter period, various kinds of physical, chemical, biological and geological observations or samplings were carried out at six stations which were located along 38°N lat. from 143° to 148°E long.

The items of observation or sampling are as follows:

(i) Hydrographic cast from surface to bottom: 7 sts. (E_1, E_2, E_3, E_4, E_4', E_5, E_6).

(ii) Water sampling for special chemical analyses: 6 sts. (E_1, E_2, E_3, E_4, E_5, E_6).

(iii) Measurement of heat flow through ocean floor: 4 sts. (E_1, E_2, E_4, E_6,).

(iv) Sampling of deep-water plankton: 2 sts. (E_2, E_6).

(v) Benthos sampling: 3 sts. (E_1, E_2, E_6).

(vi) Sampling of marine bacteria: 4 sts. (E_2, E_4, E_5, E_6).

(vii) Bottom-core sampling: 4 sts. (E_1, E_2, E_3, E_6).

(viii) Bottom dredging: 1 st. (E_4).

(ix) Detailed sounding of bottom topography: Near the bottom of the Japan Trench (E_2) and near the sea-mount (E_4).

Besides, the surface-current measurement with G.E.K., BT observation, echo sounding and geomagetic measurement were carried out underway.

The research members on board are as follows:

(i) May 10~24

Japan Meteorological Agency: J. Masuzawa, M. Yasui, H. Akamatsu, S. Ajima, T. Tsuchida, S. Hasegawa

Meteorological Research Institute: T. Nan'niti, A. Watanabe

Hydrographic Office: R. Watanabe

University of Tokyo: H. Sudo, K. Sasaki

(ii) June 5~30

Japan Meteorological Agency: J. Masuzawa (Phys. Ocean.), M. Yasui (Phys. Ocean. & Geophys.), H. Akamatsu (Phys. Ocean.), T. Sawara (Phys. Ocean.), T. Nakai (Phys. Ocean.), T. Akiyama (Chemistry), H. Yoshimura (Chemistry), R. Marumo (Plankton).

Kobe Marine Observatory: K. Katsuura (Phys. Ocean.)

Nagasaki Marine Observatory: T. Matsumoto (Phys. Ocean.)

Hakodate Marine Observatory: H. Kon (Plankton)
Meteorological Research Institute: Y. Sugiura (Chemistry), Y. Sugimura (Chemistry)
University of Tokyo: S. Uyeda (Geophys.), K. Hôrai (Geophys.), N. Taga (Bacteria), F. Seki (Bacteria), N. Nasu (Geology)
University of Kyoto: T. Shirai (Geology)
Hokkaido Gakugei University: K. Oshide (Geology)
Ochanomizu University: M. Horikoshi (Benthos)
Hydrographic Office: T. Sato (Geology)

This preliminary report has summarized the general aspects of results in all field of this expedition. The full papers will be published on the appropriate journals and they will be collected in the "Report of JEDS" published by Deep-Sea Research Commitee, Japan Society for Promotion of Science.

CONTENTS

I. Hydrographic Observations during the JEDS-4
II. Chemistry in the Japanese Expedition of Deep-Sea (JEDS-4)
III. Deep-sea Current Measurement during the JEDS-4
IV. Mid-water Animals Collected on the JEDS-4
V. Preliminary Report on the Microbiological Survey Made during the Fourth Cruise of the Japanese Deep Sea Expedition (JEDS-4)
VI. A Brief Note on the Benthic Animals on the Fourth Cruise of the Japanese Expedition of Deep Seas (JEDS-4)
VII. Geological Results in the Japanese Deep Sea Expedition in 1961 (JEDS-4)
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IX. Heat Flow Measurements over the Japan Trench during the JEDS-4

The Oceanographical Magazine
Vol. 13. No. 2, March 1962

I. Hydrographic Observation during the JEDS-4

By

Jotaro MASUZAWA* and Hideo AKAMATSU*

Six hydrographic stations were occupied along 38°N lat. between 143°E and 148°E long. In order to do exactly the geostrophic computation especially in the deep water, the level of observation was taken in the interval of 250 m in the layers from 1,000 to 4,000 m and 500 m below 4,000 m and also the tem-

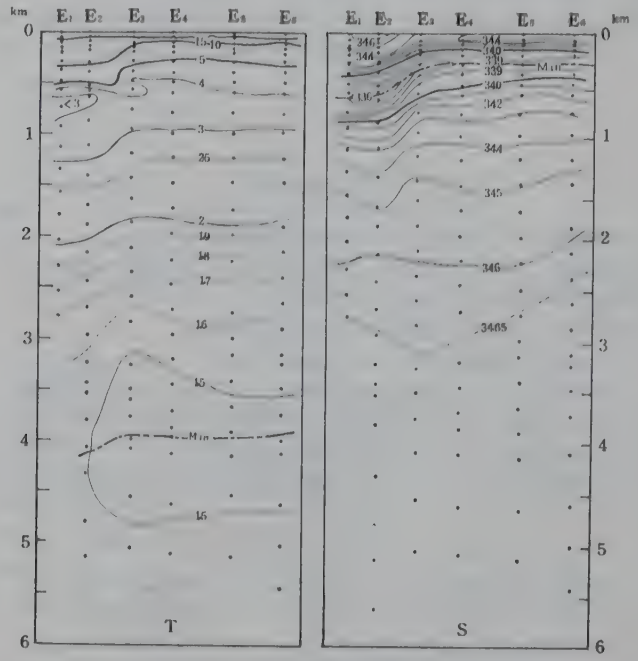

Fig. 1.1. The temperature (T: °C) and salinity (S: ‰) in the Section E (38°N, 143°~148°E) in June, 1961.

* Japan Meteorological Agency.

perature measurement and the salinity titration was made carefully.

1.1. Temperature and salinity

Since these stations are situated in the boundary region between the Kuroshio warm water and the Oyashio cold water, the distributions of current and watermass in the upper layer of this section are very complicated and changeable. Both St. E_1 and St. E_2 are in an anticyclonic warm eddy which has been cut off from the Kuroshio, so that the upper water at these stations shows the higher temperature and salinity. The cold and salinity-low water of the Oyashio origin is at the mid depth, that is, at 500 to 800 m at St. E_1—E_2 and at 200 to 400 m at St. E_3—E_6, which is a remarkable salinity minimum layer.

In the deep water below 1,000 m, both the temperature and the salinity are not so much different among the stations E_3—E_6, especially the salinity below 3,500 m is almost constant at all levels of all stations, its disperse being almost within the range of tiration errors. The temperature minimum which is a little lower than 1.5°C is distinctly recognized near 4,000 m depth of all stations east of St. E_3.

1.2. Geostrophic current

As described in details in the third section of this report, the direct measure-

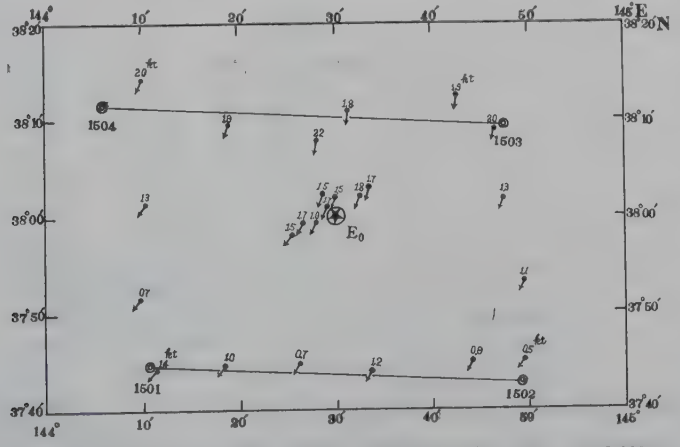

Fig. 1.2. Surface currents in the vicinity of the deep-current (3,000m) measurement station (E_0).
◎: Hydrographic cast station.

ments of deep currents were carried out at the station E_0 between St. E_2 and St. E_3 in May, 1961 (Fig. 1.2). And then, the hydrographic observations were taken at four stations (St. 1501—1504) which were located at four corners of a square surrounding St. E_0 and also the surface-currents were measured in details by G.E.K. in the neighborhood of these stations. Accrding to the results of these current measurements, the meridional component of the current-velocity at 3,000 m depth is on the average 1.0 cm/sec to the south and the average meridional component of the surface current-velocity is 63 cm/sec to the south.

On the other hand, the average meridional components of the geostrophic velocities have been calculated for the section between St. 1501 and St. 1502 and the section between St. 1504 and St. 1503. As this geostrophic computation

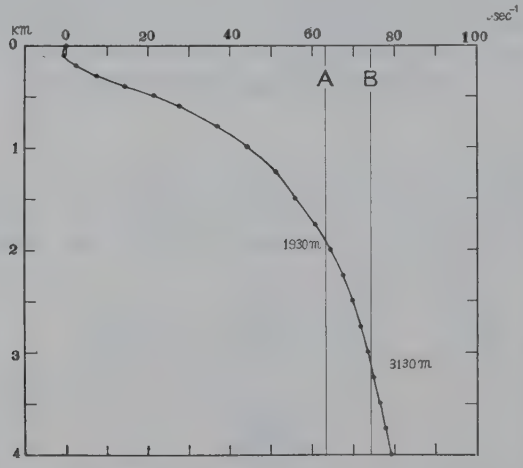

Fig. 1.3. The vertical distribution of average N-S component of geostrophic current velocity across the Section 1501～1502 and the Section 1503～1504. A: The no-motion layer referred to the average surface velocity, B: The one referred to the velocity measured at 3000m.

is referred to the average surface velocity, the level of no meridional motion is at 1,930 m depth. As it is referred to the velocity at 3,000 m, it is at 3,130 m depth. This discrepancy may be in part due to the inaccuracy of surface velocities measured by G.E.K. and also to the uncertainty of the depth

determination of the neutrally buoyant float. Furthermore, it is quite questionable whether the level of no meridional motion is at the same depth in June as the one in May and whether it is at the same depth through the whole section. However, it will be impossible to settle this problom unless we shall have more available data of deep-current measurements. Here, for the present purpose, we did the geostrophic computation assuming that the level of no meridional motion is at 2,000 m depth and at 3,000 m depth.

The results are shown in Table 1.1. The deep currents east of the Japan

Table 1.1. The N-S components of geostrophic current velocity across the Section E, relative to the 2,000 m (upper) and 3,000 m (lower). (cm/sec). Positive: Northward.

Depth	E_1-E_2	E_2-E_3	E_3-E_4	E_4-E_5	E_5-E_6
0	12.2	−67.6	12.6	− 6.6	4.7
50	9.4	−68.0	12.9	− 5.6	2.7
100	10.3	−66.9	11.5	− 4.7	1.6
200	10.4	−59.8	5.9	− 4.4	0.9
400	9.7	−41.4	− 2.0	− 3.8	− 0.0
600	9.3	−31.6	0.6	− 3.1	− 0.4
800	7.4	−23.3	3.1	− 2.3	− 1.2
1000	5.0	−15.4	3.2	− 1.7	− 1.5
1500	2.2	− 5.0	1.8	− 0.6	− 0.9
2000	0	0	0	0	0
2500	0.2	1.6	− 0.4	0.3	0.9
3000	0.5	2.3	− 0.4	0.7	1.1
3500	—	3.2	− 0.5	1.2	0.7
4000	—	3.9	− 0.3	1.4	0.4
4500	—	4.1	− 0.0	1.4	0.4
5000	—	4.1	0.1	1.4	0.4
0	11.7	−70.0	13.0	− 7.3	3.6
50	8.9	−70.3	13.3	− 6.3	1.6
100	9.9	−69.3	11.9	− 5.4	0.5
200	9.8	−62.1	6.3	− 5.1	− 0.2
400	9.2	−44.0	− 1.6	− 4.5	− 1.2
600	8.8	−34.0	1.0	− 3.8	− 1.5
800	6.9	−25.7	3.5	− 3.0	− 2.3
1000	4.4	−17.7	3.6	− 2.4	− 2.6
1500	1.7	− 7.4	2.2	− 1.4	− 2.0
2000	− 0.5	− 2.3	0.4	− 0.7	− 1.1
2500	− 0.3	− 0.8	− 0.0	− 0.4	− 0.2
3000	0	0	0	0	0
3500	—	0.8	− 0.1	0.5	− 0.4
4000	—	1.5	0.0	0.7	− 0.7
4500	—	1.8	0.4	0.7	− 0.8
5000	—	1.8	0.5	0.7	− 0.7

Trench (east of St. E_2) are genenally to the north. A little larger velocities are found just at the just east of the trench (St. E_2-E_3), the maximum velocity being 4.1 cm/sec relative to 2,000 m and 1.8 cm/sec relative to 3,000 m.

In the upper layer of the section E_2—E_3 is a strong southward current which corresponds to the eastern side of the mentioned-above anticyclonic eddy. The meridional volume transports across the section between St. E_2 and St. E_6 estimated from the dynamic computation are as follows:

0—2,000 m : $-35.9\times10^6 m^3$/sec 2,000—5,500 m : $13.3\times10^6 m^3$/sec

0—3,000 m : -43.8×10^6 3,000—5,500 m : 3.3×10^6

It is noteworthy that the deep water of $3.3\sim13.3\times10^6 m^3$ is transported per second to the north, especially by the rather stronger currents at the just east of the Japan Trench.

St. JEDS-4-E_1 (Ry 1505). 38°04′N, 143°19′E. June 7~8.

Depth (m)	T (°C)	Cl (‰)	O_2 (ml/l)	P (μg-atoms/l)	Si (μg-atoms/l)	pH	$\sum CO_2$ (millimole/l)
0	18.9	19.14	5.56	0.21	12	—	—
10	16.66	19.18	6.26	0.18	7	—	—
20	16.09	19.06	6.27	0.14	9	—	—
30	15.41	19.02	5.72	0.27	11	—	—
50	15.56	19.15	4.66	0.79	21	—	—
75	12.86	19.11	5.23	0.83	23	—	—
100	11.45	19.07	5.72	0.83	23	—	—
149	10.62	19.06	5.78	0.85	23	—	—
199	10.51	19.05	5.77	0.95	22	—	—
298	10.18	19.04	5.80	0.97	24	—	—
395	8.94	18.91	5.83	1.02	27	—	—
490	6.37	18.72	5.75	1.34	42	—	—
582	3.43	18.58	5.77	1.81	59	—	—
758	2.06	18.64	3.64	2.63	93	—	—
927	3.40	19.00	1.41	3.13	115	—	—
1136	3.25	19.01	1.01	3.29	129	—	—
1354	2.84	19.06	0.99	3.25	134	—	—
1584	2.40	19.10	1.06	3.16	143	—	—
1808	2.21	19.13	1.30	3.04	148	—	—
2041	2.04	19.14	1.61	3.00	146	—	—
2307	1.89	19.16	1.98	2.99	143	—	—
2538	1.80	19.17	2.22	3.00	143	—	—
2779	1.70	19.18	2.47	2.80	143	—	—

St. JEDS-4-E_2 (Ry 1506). 38°01′N, 144°00′E. June 13~16.

Depth (m)	T (°C)	Cl (‰)	O_2 (ml/l)	P (μg-atoms/l)	Si (μg-atoms/l)	pH	$\sum CO_2$ (millimole/l)
0	18.8	19.17	5.59	0.23	10	8.05	1.76
9	18.86	19.16	5.24	0.20	8	8.10	2.08
18	18.60	19.15	5.19	0.16	8	8.00	1.82
28	16.94	19.08	5.54	0.23	14	8.12	1.83
46	15.34	19.09	5.69	0.31	16	8.12	1.99

Depth (m)	T (°C)	Cl (‰)	O_2 (ml/l)	P (μg-atoms/l)	Si (μg-atoms/l)	pH	$\sum CO_2$ (millimole/l)
69	12.46	19.09	5.53	0.86	21	8.00	2.08
92	11.40	19.06	5.50	0.80	19	8.00	1.97
133	10.76	19.05	5.70	0.71	20	8.00	1.87
182	10.54	19.05	5.61	0.79	20	7.99	1.98
289	10.09	19.00	5.68	0.80	21	7.95	1.97
404	8.50	18.86	5.62	1.06	27	7.97	2.14
523	5.48	18.67	5.67	1.55	46	7.80	2.06
642	2.95	18.58	4.65	2.34	73	7.70	2.15
882	3.64	18.86	1.70	2.89	100	7.70	2.38
1119	3.24	18.99	0.95	3.09	122	7.50	2.44
1408	2.66	19.05	0.89	3.25	133	7.56	2.34
1699	2.32	19.10	1.08	3.25	135	7.60	2.42
1891	2.13	19.12	1.24	3.14	137	7.50	2.37
2164	1.91	19.16	1.75	3.09	142	7.50	—
2431	1.77	19.16	2.04	3.04	141	7.55	—
2695	1.68	19.17	2.43	2.97	139	7.58	2.35
2961	1.64	19.19	2.65	3.02	133	7.60	—
3230	1.58	19.19	2.91	3.14	133	7.62	—
3257	1.57	19.19	3.12	2.99	134	7.70	—
3527	1.54	19.19	3.19	2.91	136	7.70	2.33
3797	1.52	19.19	3.13	2.82	131	7.73	2.83
4066	1.50	—	—	2.87	133	7.61	2.36
3421	1.56	19.19	2.83	2.59	134	7.61	2.39
3871	—	19.19	2.99	2.63	130	7.70	2.27
4324	1.50	19.19	3.14	2.66	128	7.73	2.24
4786	1.53	19.20	3.32	2.49	130	7.80	2.22
5144	1.55	19.20	3.30	2.42	129	7.80	2.26
5618	—	19.19	3.33	2.44	129	7.85	2.28
6107	1.68	19.20	3.32	2.42	122	7.85	2.28
6596	1.74	19.20	3.34	2.40	123	7.85	2.42

St. JEDS-4–E_3 (Ry 1507). 37°57′ N, 144°51′ E. June 19.

Depth (m)	T (°C)	Cl (‰)	O_2 (ml/l)	P (μg-atoms/l)	Si (μg-atoms/l)	pH	$\sum CO_3$ (millimole/l)
0	18.1	19.03	5.33	0.25	12	8.18	1.76
10	17.78	19.03	5.37	0.19	10	8.13	2.06
20	17.61	19.02	5.42	0.19	11	8.17	1.83
30	17.19	19.02	5.56	0.23	11	8.17	1.87
50	14.22	19.00	5.54	0.57	17	8.11	2.15
75	12.21	19.00	4.98	1.01	26	8.03	2.16
100	10.90	18.98	4.84	1.20	32	8.00	2.13
145	8.79	18.90	4.97	1.30	39	7.94	2.09
193	8.05	18.85	5.07	1.52	47	7.91	2.08
290	5.86	18.69	5.66	1.65	47	7.95	2.02
387	4.57	18.73	3.62	2.45	79	7.78	2.02
483	4.00	18.79	2.62	2.89	98	7.75	2.09
579	4.26	18.79	1.76	2.94	107	7.73	2.17
769	3.70	18.98	1.17	3.16	118	7.70	2.10
958	3.05	19.03	0.97	3.27	137	7.68	2.24

Depth (m)	T (°C)	Cl (‰)	O_2 (ml/l)	P (μg-atoms/l)	Si (μg-atoms/l)	pH	$\sum CO_2$ (millimole/l)
1194	2.60	19.08	0.93	3.45	139	7.69	2.40
1433	2.34	19.11	1.09	3.41	145	7.70	—
1635	2.16	19.13	1.30	3.33	146	7.70	—
1874	1.96	19.15	1.66	3.32	146	7.70	—
2115	1.83	19.15	1.94	3.20	146	7.70	—
2357	1.72	19.17	2.24	2.94	144	7.75	2.32
2599	1.63	19.17	2.49	2.92	143	7.76	2.30
2842	1.55	19.17	2.76	2.85	140	7.78	2.25
3261	1.49	19.19	3.08	2.78	141	7.80	—
3508	1.48	19.19	3.19	2.75	133	7.79	2.32
3755	1.46	19.19	3.25	2.70	136	7.80	2.35
4004	1.45	—	—	—	—	—	—
3600	1.47	19.19	3.05	2.58	129	7.84	—
4076	1.46	19.19	3.24	2.60	135	7.80	—
4564	1.48	19.19	3.27	2.60	132	7.90	2.40
5056	1.52	19.19	3.38	2.53	132	7.89	2.40

St. JEDS–4–E_{4-1} (Ry 1508). 38°01′ N, 146°00′ E. June 20.

Depth (m)	T (°C)	Cl (‰)	O_2 (ml/l)	P (μg-atoms/l)	Si (μg-atoms/l)	pH	$\sum CO_2$ (millimole/l)
0	18.3	19.05	5.50	0.27	7	—	—
10	17.68	19.06	5.57	0.22	8	—	—
20	17.43	19.05	5.64	0.27	7	—	—
30	17.17	19.06	5.81	0.19	7	—	—
50	13.61	19.10	5.11	0.77	18	—	—
75	11.76	19.04	4.64	1.06	28	—	—
100	10.09	18.96	4.66	1.27	37	—	—
148	8.63	18.88	5.37	1.23	35	—	—
197	7.19	18.79	5.23	1.46	43	—	—
296	5.45	18.75	4.22	2.09	66	—	—
395	4.28	18.74	3.43	2.56	80	—	—
494	3.73	18.80	3.39	3.02	100	—	—
593	4.05	18.91	1.60	3.09	105	—	—
791	3.46	18.99	1.13	3.51	117	—	—
988	2.94	19.03	0.94	3.27	125	—	—
1236	2.55	19.08	0.92	3.19	134	—	—
1483	2.30	19.10	1.15	3.16	140	—	—
1915	1.94	19.14	1.75	3.02	143	—	—
2188	1.78	19.16	2.12	3.00	145	—	—
2460	1.68	19.16	2.49	2.83	143	—	—
2733	1.62	19.19	2.65	2.87	139	—	—
3006	1.55	19.18	2.91	2.79	136	—	—
3278	1.52	19.19	3.08	2.82	134	—	—

St. JEDS-4-E_{4-2} (Ry 1509). 37°56′N, 145°42′E. June 21～22.

Depth (m)	T (°C)	Cl (‰)	O_2 (ml/l)	P (μg-atoms/l)	Si (μg-atoms/l)	pH	$\sum CO_2$ (millimole/l)
0	18.4	19.02	5.28	0.19	12	8.13	—
10	17.73	19.05	5.51	0.19	11	8.16	—
20	17.47	19.06	5.57	0.13	8	8.15	—
30	17.08	19.08	5.71	0.19	8	8.15	—
50	15.00	19.07	5.54	0.44	15	8.10	—
75	12.18	19.04	4.81	1.00	24	8.00	—
100	10.48	18.98	4.94	1.20	32	7.99	—
150	8.40	18.86	5.21	1.41	38	7.94	—
200	6.74	18.77	5.25	1.61	48	7.90	—
300	4.90	18.72	4.15	2.39	68	7.80	—
400	4.71	18.81	2.81	2.69	85	7.68	—
500	3.94	18.82	2.23	2.95	97	7.60	—
600	3.74	18.89	1.54	3.09	109	7.55	—
798	3.30	18.98	0.93	3.25	123	7.50	—
995	2.96	19.03	0.91	3.35	131	7.50	—
1243	2.54	19.07	0.90	3.30	136	7.51	—
1491	2.27	19.10	1.19	3.29	141	7.53	—
1731	2.10	19.12	1.40	3.16	141	7.65	—
1980	1.90	19.14	1.75	3.11	144	7.64	—
2227	1.78	19.15	2.08	3.19	140	7.66	—
2474	1.69	19.17	2.41	3.06	141	7.67	—
2721	1.62	19.18	2.58	3.00	141	7.70	—
2968	1.57	19.18	2.73	2.85	137	7.70	—
3208	1.51	19.19	2.96	2.94	137	7.72	—
3458	1.49	19.19	3.13	2.90	137	7.75	—
3707	1.48	19.20	3.20	2.81	135	7.79	—
3957	1.47	—	—	—	—	—	—
3872	1.48	19.20	3.10	2.70	135	7.80	—
4125	1.47	19.19	3.14	2.66	132	7.80	—
4616	1.48	19.19	3.29	2.59	134	7.81	—
5110	1.53	19.19	3.30	2.57	129	7.85	—

St. JEDS-4-E_5 (Ry 1510). 38°00′N, 146°57′E. June 22.

Depth (m)	T (°C)	Cl (‰)	O_2 (ml/l)	P (μg-atoms/l)	Si (μg-atoms/l)	pH	$\sum CO_2$ (millimole/l)
0	18.7	19.04	5.40	0.13	13	—	—
10	17.57	19.03	5.64	0.31	14	—	—
20	16.72	19.04	5.95	0.34	12	—	—
30	15.73	19.06	5.83	0.34	16	—	—
50	12.96	19.08	5.27	0.95	24	—	—
75	11.06	19.00	4.89	1.17	32	—	—
100	9.76	18.93	4.72	1.33	38	—	—
149	8.39	18.87	4.95	1.43	44	—	—
199	6.72	18.79	5.07	1.73	53	—	—
298	4.89	18.75	3.83	2.55	78	—	—
398	4.39	18.79	2.91	2.64	90	—	—
497	4.34	18.89	1.88	2.96	107	—	—
596	3.94	18.94	1.46	3.14	114	—	—
787	3.28	19.00	1.04	3.29	125	—	—
989	2.91	19.03	0.97	3.49	134	—	—

Depth (m)	T (°C)	Cl (‰)	O_2 (ml/l)	P (μg-atoms/l)	Si (μg-atoms/l)	pH	$\sum CO_2$ (millimole/l)
1232	2.50	19.08	0.99	3.42	142	—	—
1474	2.29	19.10	1.15	3.30	145	—	—
1739	2.09	19.13	1.51	3.11	144	—	—
1989	1.89	19.14	1.83	3.14	144	—	—
2238	1.78	19.16	2.16	3.02	144	—	—
2488	1.67	19.18	2.52	3.07	141	—	—
2738	1.61	19.18	2.76	3.02	141	—	—
2988	1.54	19.19	2.96	2.87	139	—	—
3160	1.53	19.19	3.03	3.02	138	—	—
3409	1.51	19.20	3.31	2.89	137	—	—
3658	1.49	19.20	3.20	2.89	136	—	—
3907	1.47	—	—	—	—	—	—
3902	—	19.19	3.26	2.69	137	—	—
4147	1.47	19.19	3.34	2.69	134	—	—
4636	1.49	19.19	3.44	2.71	135	—	—
5126	1.52	19.19	3.48	2.76	131	—	—

St. JEDS–4–E_6 (Ry 1511). 38°01′N, 148°00′E. June 23～24.

Depth (m)	T (°C)	Cl (‰)	O_2 (ml/l)	P (μg-atoms/l)	Si (μg-atoms/l)	pH	$\sum CO_2$ (millimole/l)
0	18.9	19.06	5.30	0.21	13	8.16	—
10	18.79	19.07	5.34	0.23	13	8.15	—
20	18.30	19.07	5.60	0.25	13	8.15	—
30	17.58	19.03	5.78	0.31	14	8.17	—
50	14.60	19.05	5.72	0.42	17	8.12	—
75	11.90	19.02	5.03	0.98	25	8.03	—
100	10.78	18.97	4.81	1.19	35	8.01	—
146	8.52	18.86	5.41	1.21	38	8.00	—
195	7.28	18.79	5.62	1.41	45	7.96	—
293	5.32	18.74	4.16	2.16	72	7.81	—
391	4.69	18.81	2.77	2.63	90	7.71	—
489	4.25	18.87	2.00	3.05	101	7.63	—
588	4.09	18.92	1.55	3.00	107	7.61	—
783	3.41	18.98	1.11	3.10	121	7.55	—
980	2.98	19.04	0.99	3.19	133	7.54	—
1226	2.50	19.08	0.96	3.39	140	7.53	—
1472	2.28	19.12	1.16	3.43	139	7.53	—
1895	1.97	19.15	1.70	3.19	141	7.68	—
2143	1.81	19.16	2.05	3.11	148	7.70	—
2391	1.70	19.18	2.36	3.00	144	7.71	—
2643	1.62	19.19	2.71	2.99	142	7.60	—
2891	1.57	19.19	2.89	2.89	140	7.64	—
3140	1.53	19.19	3.01	2.83	138	7.70	—
3235	1.52	19.19	3.09	2.83	139	7.68	—
3485	1.51	19.19	3.22	2.81	138	7.70	—
3735	1.48	19.19	3.27	2.74	135	7.72	—
3985	1.48	—	—	—	—	—	—
4108	1.49	19.20	3.29	2.68	135	7.73	—
4608	1.49	19.20	3.41	2.64	132	7.74	—
5024	1.53	19.20	3.51	2.68	132	7.74	—
5436	1.57	19.20	3.49	2.81	133	7.78	—

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II. Chemistry in the Japanese Expedition of Deep Sea (JEDS-4)*

By

Yasuo Miyake**, Yoshio Sugiura***,
Yukio Sugimura***, Tsutomu Akiyama****,
and Hirozo Yoshimura****

Chlorinity, dissolved oxygen, silicate-Si, phosphate-P, total carbon dioxide and pH were determined under the collaboration of Oceanographic Section of the Meteorological Agency and the Meteorological Research Institute.

The methods of chemical analyses of these constituents were already mentioned in the previous report.

Vertical distribution of dissolved oxygen at the cross section along the observation line across the Japan Trench is shown in Fig. 2.1. At the surface was found an uniform layer exceeding 5 ml/l in dissolved oxygen content. An evident rate of decrease with depth of dissolved oxygen is found in the layer below the upper uniform layer, where dissolved oxygen content decreases remarkably from 5 to 2 ml/l at the span of 300 m in thickness. In view of horizontal distribution of shallower layer, a boundary was observed near the Japan Trench, at the west side of which larger content is observed than at the east side at the same depth. The minimum layer of dissolved oxygen exists approximately at the depth of 1,100 to 1,400 m. The minimum contents at each station are almost the same, ranging from 0.9 to 1.0 ml/l. Below the minimum layer the gradual incresae was seen to the depth of 3,500 m and to the value of 3.2 ml/l. In the layers deeper than 3,500 m, no noticeable change was detected not only vertically but also horizontally.

The general trend of the vertical distribution of phosphate and silicate is rather similar as seen in Fig. 2.2. A remarkable gradient was found at subsurface at which the concentrations of phosphate and silicate increase with the

* JEDS Contribution No. 30.
** Tokyo University of Education.
*** Meteorological Research Institute.
**** Japan Meteorological Agency.

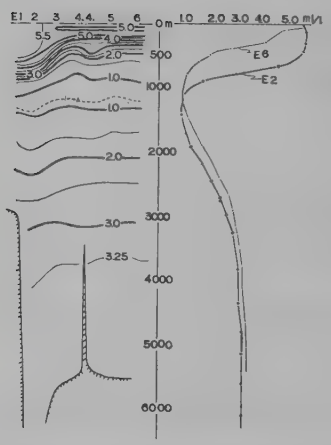

Fig. 2.1 Vertical distribution of dissolved oxygen and variations of contents at two representative points of east and west side of a boundary.
------: minimum content layer

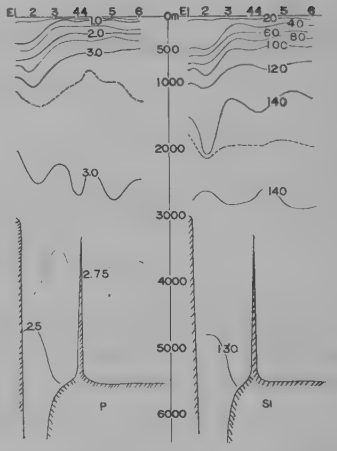

Fig. 2.2 Vertical distributions of phosphate-P and silicate-Si (μg-atoms/l).
------: maximum content layer

depth. But, the depth having the large gradient is greater at the west side of the Japan Trench than at the east side. The maximum content of phosphate is about 3.4 μg-atoms/l and the depth of its appearance covers 800 to 1,400 m. The maximum content of silicate is 145 μg-atoms/l and the depth of its appearance is about 2,000 m, though the peak in the vertical distribution of silicate is not clear. Below the maximum layer both constituents gradually decrease to 2.7 μg-atoms/l in the phosphate content and to 130 μg-atoms/l in the silicate content. In the layers deeper than 3,000 m, no significant change is detected in the similar way as mentioned at the oxygen distribution.

The vertical distribution of total carbon dioxide was also studied. The maximum appeared at about 1,500 m or at slightly below the oxygen minimum layer. The maximum value is about 2.4 milli mole/l. The lowest value is about 1.7 milli mole/l and was found at the surface.

Water samples were collected for analyses of total phosphorus, rare earths, radium, thorium and dissolved carbohydrates. The results of analyses will be later reported elsewhere.

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III. Deep-sea Current Measurement during the JEDS-4*

By

Masashi YASUI** and Tosio NAN'NITI***

The deep-sea current measurement by means of the neutral buoyancy float was carried out in the neighbourhood of St. E_0 (38° N, 144.5° E) in May, 1961. In this region, an accuracy of Loran seems to be about ±0.5 nautical miles in

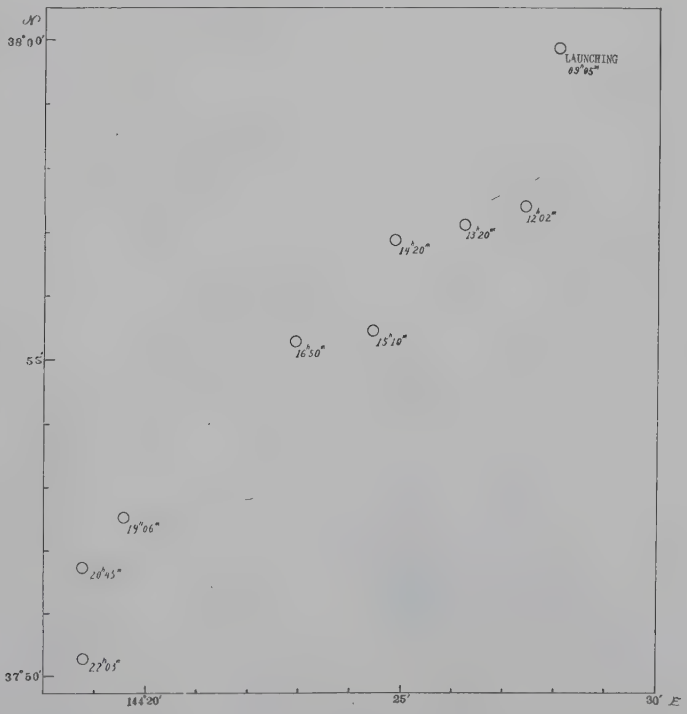

Fig. 3.1. Trajectory of float in 1,000 m water.

* JEDS Contribution No. 31.
** Japan Meteorological Agency.
*** Meteorological Research Institute

the absolute values. It is, however, conceivable that the relative position of successive reckonings would have an accuracy much better than this value. Examining the results of the previous operation in September, 1960, we concluded that the accuracy of the ship's position obtained by Loran is better than that which is required for the purpose, provided the float drifted more than a mile in the whole interval of observation. Therefore, the entire operation in this cruise was carried out without mooring buoy.

In the operation, three floats were released into two layers: two at 1,000m

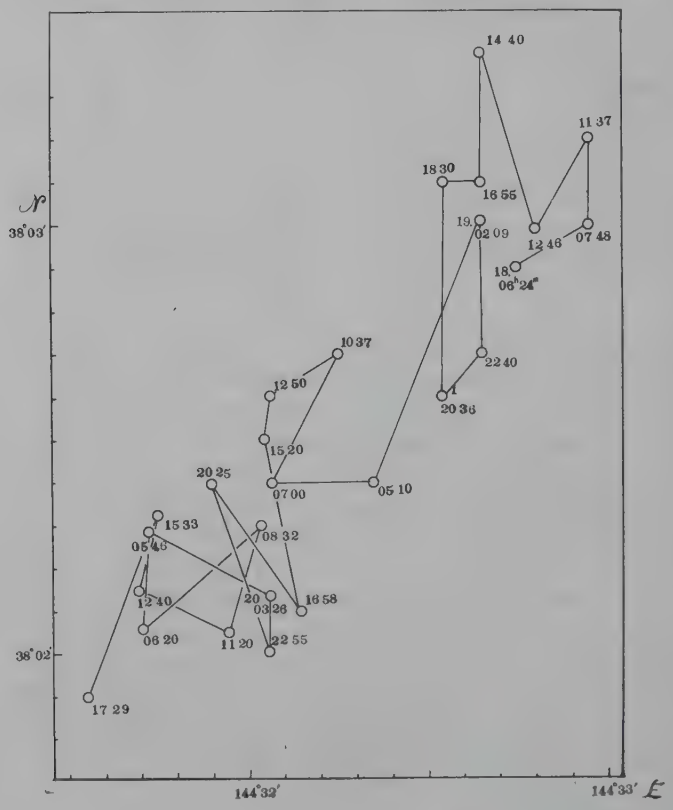

Fig. 3.2. Trajectory of float in 3,000 m water.

depth and one at 3,000 m depth. At 1,000 m depth, the current was fairly fast and this was ascertained by the following float at the same depth.

The trajectory of the float in water of 1,000 m and 3,000 m depth are summarized in Fig. 3.1 and 3.2. The relationships between the time and the latitude or longitude of floats are shown in Fig. 3.3. From these data, the mean velocities are computed by the least square method as follows; 55.4 cm/sec in

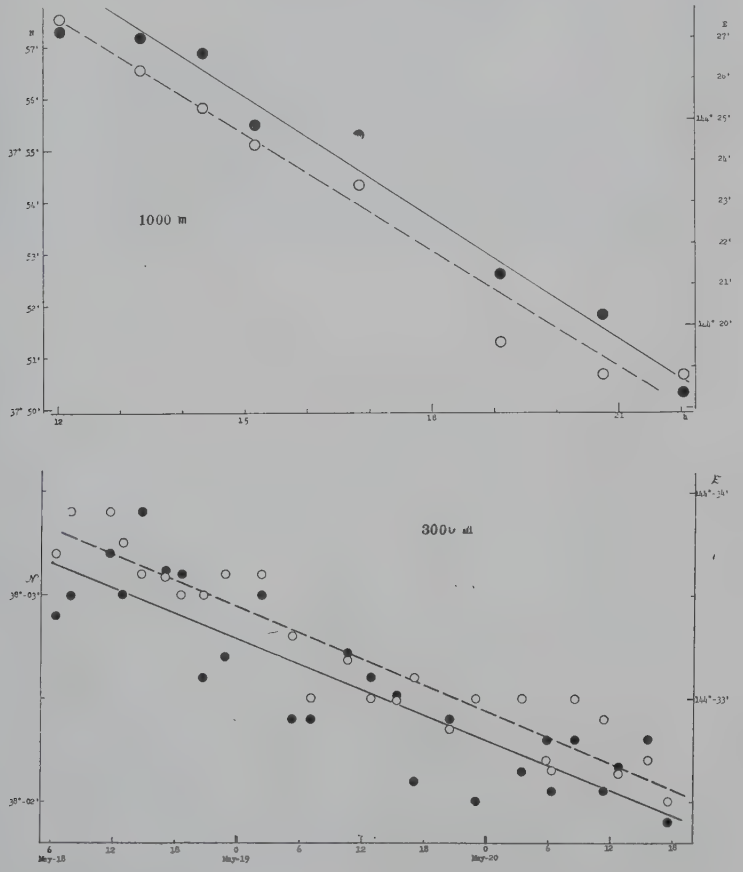

Fig. 3.3. Time rate of movement of the float in north and east component.
Upper; 1,000 m depth. Lower; 3,000 m depth.
●; latitude. ○; longitude.

the direction of 223° in 1,000 m depth and 1.4 cm/sec in the direction of 219° in 3,000 m depth.

In this operation, hydrographical casts to 4,000 m depth were carried out at four corners of the square enclosing the area of the deep-current measurement. The surface current was also measured continuously along four sides of this square by means of G.E.K. From the data, the current profile referred to the mean surface current is dynamically computed.

The authors were a little surprised by the magnitude 55.4 cm/sec in 1,000 m water. However, the result of the dynamic computation shows that the difference between the north-south components of the currents in water of 1,000 m and 3,000 m depth is about 35 cm/sec, while the difference between them derived from the results of the neutral-buoyancy float method is about 40 cm/sec. Therefore, the magnitude of 55.4 cm/sec seems to be not so unreasonable.

The Oceanographical Magazine
Vol. 12. No. 2, March 1962

IV Mid-water Animals Collected on the JEDS-4*

By

Yoshiyuki MATSUE,** Ryuzo MARUMO,***
Yuzo KOMAKI** and Hisanori KON****

The fourth cruise of the Japanese Expedition of Deep Seas (JEDS-4) was made by the Ryofu Maru of the Japan Meteorlogical Agency in the sea area east of Japan along 38°N in July 1961. On the present cruise deep-sea plankton collection was carried out, as well as on the second and the third cruises. In this paper, a general view of the collection method and the result will be given. Further detailed studies on taxonomy and ecology will be made on each plankton group by specialists.

The net used, "130-cm conical net", is shown in Fig. 4. 1. The mouth diameter is 130 cm. The length of the filtering part is 500 cm, being made of nylon bolting cloth, and the mesh aperture is 4 mm^2 in the upper 400-cm part and 0.33 mm^2 in the lower 100-cm part. A 80-kg lead was attached at the end of four additional ropes. The net connected with the end of the tapered wire rope was hauled up at the speed of 20-40 m per minute from a definite depth to the surface. The collection was made at two stations. Five vertical hauls were made at station E_2 with the depth of 7300 m, 38°01′N, 144°00′E, in the Japan Trench. Three vertical hauls were made at station E_6 with the depth of 5600 m, 38°01′N, 144°00′E. It could not be avoidable that plankton samples were more or less contaminated by surface plankton, because we did not use any closing apparatus on the present expedition.

The counting of specimens was made for each taxonomical plankton group and the result is given in Table 4. 1. For reference, values of water temperature and chlorinity at stations E_2 and E_6 are tabulated in Table 4. 2. Copepods were most predominant in number and chaetognaths were next to them. Such a result was also obtained in the cases of the JEDS-2 (Y. SUYEHIRO

* JEDS Contribution No. 32.
** University of Tokyo.
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and others, 1960) and the JEDS-3 (Y. MATSUE and others, 1961; R. MARUMO, 1961). Coelenterates, crustacean decapods, and deep-sea fishes attracted our

Table 4·1. Individual numbers of plankton animals collected by 130-cm conical net in 1961 (JEDS-4).

Station		E_2					E_6		
Hauling depth (m)		580→0	1000→0	3000→0	5000→0	7000→0	1000→0	3000→0	5500→0
Wire angle		40°	0°	15°	13°	15°		8°	0°
Location (N, E)		38–02 143–49 ↓ 38–03 143–47	38–02 143–54 ↓ 38–02 143–54	37–52 143–50 ↓ 37–51 143–48	37–56 143–55 ↓ 57–56 143–53	37–55 143–57 ↓ 37–53 143–54	38–13 147–54 ↓ 38–13 147–54	38–06 148–02 ↓ 38–06 148–02	38–04 148–01 ↓ 38–05 148–01
Date		June 17 1258 ↓ 1320	June 18 1325 ↓ 1348	June 13 1606 ↓ 1730	June 16 1328 ↓ 1600	June 15 0745 ↓ 1210	June 26 0237 ↓ 0305	June 25 0940 ↓ 1055	June 25 2154 ↓ 2355
Radiolaria		+	+	+	+	+	+	+	+
Coelenterata		85	130	224	168	268	241	242	108
Chaetognatha	(a)	380	311	1041	670	657	362	448	161
	(b)			86	58	37	1	58	74
Polychaeta			5	4	6	2	18	22	12
Crustacea: Copepoda	(l)	661	1648	2332	4367	3296	2852	2948	2172
	(s)	368	488	472	1800	528	864	1920	560
Crustacea: Cladocera			4	40	8			8	8
Crustacea: Ostracoda		30	212	112	406	155	150	222	198
Crustacea: Mysidacea		1	10	17	41	1	11	9	5
Crustacea: Euphausiacea		38	66	139	21	336	402	147	108
Crustacea: Amphipoda		6	28	47	54	52	51	70	54
Crustacea: Decapoda		8	7	47	11	27	16	24	16
Pteropoda			4	1		1		1	7
Cephalopoda		3	2	5	1	3	1		
Thaliacea		13	44	40	41	46	108	154	104
Pisces		12	18	55	14	18	13	20	16
Pisces scale			8	840	72	24	56	864	20
Egg				3					2

(a), (b): Intestine is colored with orange oil grobules for (b) and not colored for (a).
(l): larger than 1.5 mm
(s): smaller than 1.5 mm

attention, though not large in number, because of the beauty coloration and the various shape. Photographs of some specimens are presented in Figs. 4. 2 to 4. 8. We found a specimen of *Periphylla* and a specimen of *Atolla*, which

are both typical deep-sea jellyfishes with dark brown color. Of chaetognaths, orange-colored specimens belonging to *Eukrohnia* were abundant in samples collected from deeper layers but were hardly found in samples from the upper 1000 m layer. This coloration is originated from oil grobules in their intestine.

Table 4.2. Values of water temperature (°C) and chlorinity (‰) at stations E_2 and E_6.

Depth (m)		0	100	200	500	1000	1500	2000	2500	3000	4000	5000	6000	6500
St. E_2	T	18.8	11.18	10.48	6.22	3.43	2.55	2.03	1.74	1.62	1.50	1.54	1.66	1.72
	Cl	19.17	19.06	19.05	18.70	18.94	19.06	19.14	19.17	19.19	19.19	19.20	19.20	19.20
St. E_6	T	18.9	10.79	7.15	4.23	2.94	2.27	1.89	1.66	1.55	1.48	1.53		
	Cl	19.06	18.97	18.79	18.87	19.04	19.12	19.16	19.18	19.19	19.20	19.20		

Fresh scarlet coloration was recognized in a polychaete annelid, decapod crustaceans (*Gennades* and *Hymenodora*) and mysidaceans. Two specimens of white amphipod crustaceans were obtained from a deeper-layer collection in the Japan Trench. Among fishes, *Cyclothone* was most predominant.

References

Y. SYEHIRO and others (1960): Notes on the sampling gears and the animals collected on the second cruise of the Japanese Expedition of Deep Seas (JEDS-2). *Oceanogr. Mag.*, **11** (2), 187-200.

Y. MATSUE, R. MARUMO and Y. KOMAKI (1961): Notes on the mid-water animals collected in the third cruise of Japanese Expedition of Deep Seas (JEDS-3). *Oceanogr. Mag.*, **12** (2), 219-222.

R. MARUMO (1961): Research on deep-sea animals by the "Ryofu Maru". *Information Bulletino on Planktology in Japan*, **7**, 1-7 (in Japanese).

Fig. 4. 1. 130-cm conical net.

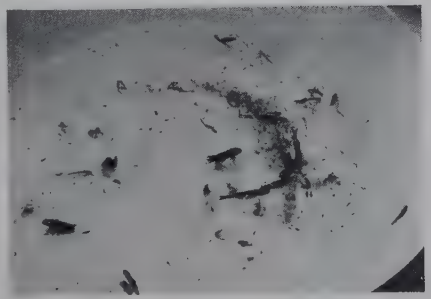

Fig. 4. 2. Plankton organisms obtained by a haul from 7000 m depth to the surface at st. E2.

Fig. 4. 5. Vermilion ostracods (st. E2, 5000→0 m).

Fig. 4. 6. Copepods (st. E2, 7000→0 m).

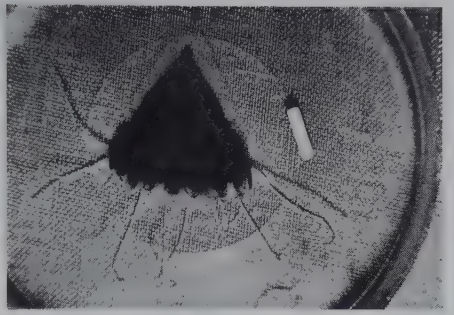

Fig. 4. 3. A deep-sea jellyfish belonging to genus *Periphylla* (st. E6, 3000→0 m). The scale shows 1 cm.

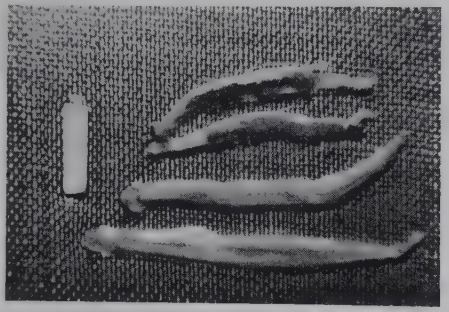

Fig. 4. 4. Chaetognaths (st. E6, 5500→0 m). The intestine of the upper two specimens is colored with orange oil grobules. The scale shows 1 cm.

Fig. 4. 7. A white deep-sea amphipod (st. E2, 7000→0 m).

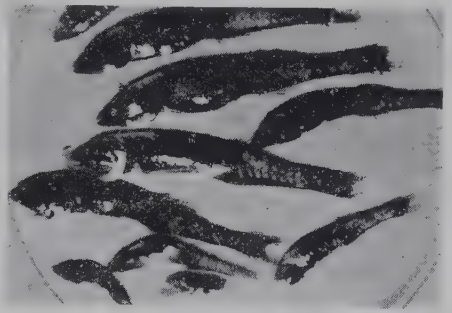

Fig. 4. 8. Deep-sea fishes belonging to genus *Cyclothone* (st. E2, 7000→0 m).

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V. Preliminary Report on the Microbiological Survey made during the Fourth Cruise of the Japanese Deep Sea Expedition (JEDS-4)*

By

Nobuo Taga** and Fumitake Seki**

1. *Introduction*

The wide distribution in the sea of bacteria and allied microbes and their various effects on biological and geochemical conditions in the marine environment have been recognized for nearly a century. Only relatively little attention, however, has been given to the development of new techniques to obtain quantitative information of these microbes in the field and for world-wide surveys to realize their ecological significance in various parts of the oceans.

The general features of the distribution and the occurrence of marine bacteria has been reviewed by ZoBell (1946) through discussing and summarizing fragmentary studies made at coastal or relatively shallow regions of the sea from the ecological view-point. Recently, in several parts of the oceans, vertical distributions of microorganisms and their relationships with water masses or with hydrographic conditions have been appraised by Kriss (1959) and other investigators. However, there still exist several problems to be solved concerning ecological and physiological aspects of marine microorganisms found in various deeper parts of the oceans, as well as several new techniques suitable to microbiological work at sea.

In the present investigation, the main objective was a reconnaissance to investigate the vertical distribution of bacteria, actinomyces and yeasts in the deeper parts of the open sea and to examine whether some of the microbiological techniques could be effectively used on a research ship. This report represents only an outline of the microbiological survey made during the cruise of JEDS-4, but the detailed results of the survey will be published in near future.

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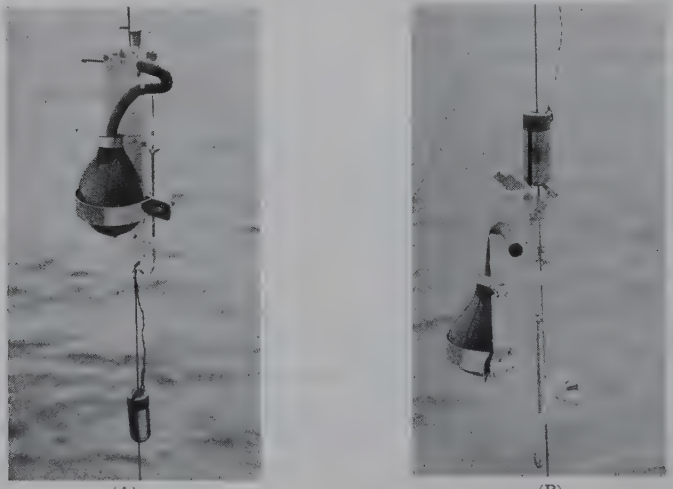
* JEDS Contribution No. 33.

** Department of Fisheries, Faculty of Agriculture, University of Tokyo.

Acknowledgements: Acknowledgements are due to the Committee of the Japanese Deep Sea Expedition for giving us the opportunity of making the microbiological survey during this cruise. The authors wish to express their appreciation to Prof. Dr. Yoshiyuki MATSUE of our Department in University of Tokyo for his encouragement and helpful advices. Special acknowledgement is also due to Prof. Dr. Claude E. ZoBELL, Scripps Institution of Oceanography, University of California, who gave his kind advices for our beginning microbiological work at sea to one of the authors. The assistance of the research members and crew of the M. S. Ryofu Maru who helped to collect microbiological samples in this cruise is acknowledged. This project was supported in part by two grants: the Special Fund for the Promotion of Scientific Research of the Science and Technics Agency, and the Scientific Research Fund of the Ministry of Education of Japan.

2. *Methods*

Sampling method—Sea water samples for microbiological analysis were collected in sterile J-Z bacteriological water samplers (ZoBELL, 1941 & 1946)



(A) Before sampling. (B) After sampling.

Fig. 5·1. View of the J-Z bacteriological water sampler before and after sampling.

using collapsible rubber bottles (volume: 200 m*l*.), from the depths: Surface, 20, 50, 100, 200, 400, 600, 800, 1000, 1500, 2000, 3000 and 4000 meters, at the three Stations, E_4, E_5, E_6 of JEDS-4. As illustrated by Figure 5.1, the messenger system on the metal frame of the J-Z sampler has been slightly improved from its original type; no failures ware experienced in collecting water samples *seriatim* from various depths.

Media for cultivation—For enumeration or cultivation of bacteria and actinomyces in sea water samples, the modified formula of Medium 2216E (Oppenheimer and ZoBell, 1952) was used; *i. e.*, Poly-peptone*, 5 g; Yeast extract*, 1 g; Ferric phosphate soluble (Merck Co., U. S. A.), 0.1 g; Agar, 15 g; aged sea water, 1000 m*l*; pH adjusted 7.6 to 7.8. Carlucci and Pramer (1957) have confirmed the superiority of the original formula of Medium 2216 E, but the present writers have also obtained satisfactory results by the modified formula above-mentioned. For the purpose of enumerating and isolating yeasts from sea water, the following medium formula was used; *i. e.*, Glucose, 20 g; Poly-peptone*, 10 g; Yeast extract*, 5 g; Agar, 20 g; aged sea water, 1000 m*l*; the pH was adjusted by adding 10% Lactic acid (10 m*l* per liter) before using. These media could be conveniently transported and stored by pouring them seperately into each of 100 m*l*-volume screwed-cap glass-bottles and then sterilizing them. Agar plates for cultivation work aboard ship were prepared by remelting these bottled media; *i. e.*, 10 m*l* of media liquefied by steam were poured aseptically into each of the sterile petri dishes (diameter: 60 mm.), then solidified by cooling.

Method of enumeration—After the sea water samples in the rubber bottles of the J-Z samplers were transferred aseptically into sterile glass stoppered bottles, 10 to 80 m*l* water samples (10 to 50 m*l* for bacteria, 40 to 80 m*l* for yeasts) were taken from each ef the stoppered bottles and were passed through a steril 50-mm type Co. 5 Membrane filter to concentrate the microorganisms. The filters were sterilized at 120°C for 15 minutes and then stored in sterilized distilled water until used. The inoculated filters were placed on nutrient agar plates which were solidified beforehand in sterile 60-mm petri dishes. These inoculated dishes were incubated at 20° to 23°C for two weeks or more. Macrocolonies which were grown on the filters could be easily defined and counted by the naked eyes, and some of the colonies were transferred by a plutinum

*..... Manufactures of Daigo Eiyo Kagaku Co. in Japan.

loop to agar slants in order to obtain the isolated strain after enumeration. By drying the filter on which visible colonies were grown in a dryer at 100°C it could be safely preserved for the purpose of colonies count later. The filter method procedure is nearly the same as "macrocolony membrane filter method" presented previously by JANNASCH and JONES (1959).

3. Outline of results obtained

The number of heterotrophic microorganisms detected by the macrocolony membrane filter method of enumeration from oceanic regions at the Pacific Ocean are presented in Table 5.1. As observed in this Table, heterotrophic bacteria which could grow on nutrient agar under normal pressure** were

Table 5.1. Vertical distribution of heterotrophic microorganisms found in sea water at three Pacific Ocean Stations.

Depth (m)	Microbial Number per 1000 m*l* of Sea Water								
	Station: E_4			Station: E_5			Station: E_6		
	Bact.	Acti.*	Yeasts	Bact.	Acti.*	Yeasts	Bact.	Acti.*	Yeasts
0	3900		75	4800		?	400		?
20	200		130	900		?	3900		?
50	500		?	8300		?	350		?
100	100		130	1100		?	3300		?
200	250		20	150		?	2800		?
400	550	11%	?	580		?	380		?
600	300		?	75		?	230		?
800	2100		40	50		?	130		?
1000	75	33%	?	50		?	50		?
1500	<25		?	100	25%	?	630		38
2000	75		?	180		?	25		?
3000	—		—	—		?	220		?
4000	—		—	420		38	40		?

(Notes) *……% of bacteria identified as actinomyces.
?……No yeasts detected in the presently examined volume of 40–80 m*l*.

**…… As for the effect of hydrostatic pressure upon the growth of marine bacteria, the the following facts have been observed beforehand. Most of the bacteria taken from depths of 7000 to 10000 meters grow only when incubated at pressures characteristic of their natural habitat, *i. e.*, 700 to 1000 atm (ZOBEEL & MORITA, 1957). On the other hand, the growth of the bacteria taken from depths of less than 1000 meters is inhibited when cultures are compressed to 200 to 400 atm at optimum temperature (OPPENHEIMER & ZOBELL, 1952).

widely found in all water mass to depths of at least 4000 meters. The populations of bacteria at any depths were dominant as compared with the numbers of actinomyces or yeasts, although such bacterial populations in oceanic regions seemed to be generally considerably smaller than in neritic regions of the sea. Relationships between the distributions of these microorganisms and the hydrographic conditions will be discussed later in detail and compared with the hydrographical data by other member of the cruise.

In the present survey, many kinds of microbial strains have been also isolated from several depths observed in this cruise; they were about eighty strains of bacteria, three strains of actinomyces, and about ten strains of yeasts. Various characteristics of these isolated strains are continuously being examined in detail.

The macrocolony filter method might be suggested as one of the suitable techniques to be effectively used aboard ship for the purpose of cultivating and enumerating the living microbes in sea water at the open sea. It is only a defect in this method, however, that the surface of cultivation agar plates is occasionally contaminated by the mold fungi during the long incubation. The preventive methods of the mold contamination are also being examined at present.

References

CARLUCCI, A. F. and PRAMER, D. (1957): Factors influencing the plate method for determining abundance of bacteria in sea water. *Proc. Soc. Expt. Biol. Med.*, **96**: 592–94.

JANNASCH, H. W. and JONES, G. E. (1959): Bacterial populations in sea water as determined by different methods of enumeration. *Limnol. Oceanogr.*, 4 (2): 128–39.

KRISS, A. E. (1959): Distribution of water masses in the Indian Ocean and in the Central Pacific Ocean according to microbiological data. Preprints; International Oceanographic Congress in 1959, American Assoc. Advanc. Sci., Washington, D. C.; 555–58.

OPPENHEIMER, C. H. and ZOBELL, C. E. (1952): The growth and viability of sixtythree species of marine bacteria as influenced by hydrostatic pressure. *J. Mar. Res.*, **11**: 10–18.

ZOBELL, C. E. (1941): Apparatus for collecting water samples from different depths for bacteriological analysis. *J. Mar. Res.*, **4**: 172–88.

—— (1946): "*Marine Microbiology*". Chronica Botanica Co., Waltham, Mass., 240 pp.

—— (1954): Some effects of high hydrostatic pressure on apparatus observed on the Danish Galathea Deep-Sea Expedition. *Deep-Sea Res.*, **2**: 24–32.

—— and MORITA, R. Y. (1957): Deep sea bacteria. *Galathea Rep.*, **1**: 139–54.

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Vol. 13. No. 2, March 1962

VI. A Brief Note on the Benthic Animals on the Fourth Cruise of the Japanese Expedition of Deep Seas (JEDS-4)*

By

Yasuo Suyehiro,** Yaichiro Okada***, Masuoki Horikoshi**** and Eiji Iwai**

The fourth cruise of the Japanese Expedition of Deep Seas (JEDS-4) was carried out from June 5th to 30th of 1961, on board the research vessel Ryofu Maru. On this cruise, benthic animals were collected at 4 stations, off the Pacific coast of northeastern Honshû, the main island of Japan. A beam trawl (3 stations) and a rectangular dredge (1 station) were employed, both of which have been described in the previous paper (Suyehiro *et al.*, '60). The locations and depths of these stations are as follows:

St. E 1. Flat area off Sendai: 38°03′N, 142°52′E, 1,700 m. (trawl).

St. E 2. Eastern slope of the Japan Trench: 38°00′N, 144°05′E—37°57′N, 143°57′E, 6,700—7,340 m. (trawl).

St. E 4. Near the top of a sea mount: 38°00′N, 146°00′E, 3,600—3,400 m. (dredge).

St. E 6. Flat bottom in the peripheral part of the Pacific basin: 38°09′N, 148°00′E, 5,650 m. (trawl).

The beam trawl was operated by the biologists on board the vessel directed by M. Horikoshi, and the dredge was towed mainly by the geologists (directed by Dr. N. Nasu). The detailes of the beam trawl towing data are shown in Table 6.1. The detailed location is indicated by a set of positions obtained at the times of hitting and leaving the bottom. These times could be found from observation of rather abrupt changes in the wire angle and in the speed of the vessel, together with a comparison between the depth of the sea and the length of paid out wire. On this cruise, the wire was much over-paid to ensure the success of the trawling in abyssal and hadal (ultra-sbyssal) depths.

* JEDS Contribution No. 34.
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Table 6·1. Towing data of the beam trawl.

Station	E_1	E_2	E_6
Detailed location	38°03.3′N, 142°52.5′E—38°05.0′N, 142°52.0′E.	38°00.0′N, 144°05.0′E—37°57.0′N, 143°59.4′E.	38°06.4′N, 148°01.0′E—38°11.2′N, 147°59.0′E.
Date	June 6–7, 1961	June 8–9, 1961	June 26, 1961
Depth	1,690—1,650 m	6,700—7,340 m	5,655—5,650 m
Pay out	2,500 m	11,000 m	8,000 m
Time:			
Shooting	23.50	16.55	03.30
Hitting bottom		20.30	06.15
Towing	01.00	22.20	08.30
Hauling	04.30	02.15	11.30
Leaving bottom		05.50	13.30
Stop hauling	05.30	10.05	17.20

In the first operation on this cruise at St. E_1, the beam trawl came up with the rear part of the trawl-bag twisted around the trawl-head, although a quantity of material scooped from the bottom was found in the front part of the bag. To avoid such an accident thereafter, the weight of the two plumbs at the rear end of the trawl-bag (15 kg each) was increased to 30 kg each, and the trawl was always lowered slowly, rear end first. On this cruise, a screening net of rough mesh was set diametrically inside the trawl-bag just in front of the inside net, in order to stop large stones midway with the bag. This screening net worked well, and was found to be rather effective in protecting organisms from being crushed as had occurred on the previous cruise (JEDS-2).

A number of benthic animals from a wide range of groups were brought up from abyssal and hadal depths by the beam trawl. They amount to 1,272 in total number, excluding innumerable specimens of a polychaete species (Maldanidae ?) collected at St. E_1, and have been classified provisionally into 83 forms. Although further studies by specialists which are expected to be completed in the near future, should reveal more precise figures, the details of systematic grouping and number of species are shown in Table 6.2.

As has been alluded to above, a polychaete species Maldanidae ?) living in a slender, sand-bearing tube was collected in large numbers at St. E_1. It is very likely that these polychaete tubes form an extensive covering on the

Table 6·2 Benthic animals collected by the beam trawl (JEDS-4: June 1961)

Station	St. E_1		St. E_2		St. E_6	
Depth	1,700 m		6,700—7,400 m		5,650 m	
Animal group	species	number	species	number	species	number
PROTOZOA	2*	468*	—	—	—	—
(Foraminifera)	(2)*	(468)*	—	—	—	—
PORIFERA	1	1	—	—	—	—
COELENTERATA	1	1	1	4	3	10
(Scyphozoa)	—	—	—	—	(1)	(6)
(Alcyonaria)	(1)	(1)	—	—	—	—
(Actiniaria)	—	—	(1)	(4)	(2)	(4)
ANNELIDA	6	33**	6	81	5	7
(Polychaeta)	(6)	(33)**	(5)	(68)	(2)	(3)
(Echiuroidea)	—	—	(1)	(13)	(1)	(1)
(Sipunculoidea)			—	—	(2)	(3)
MOLLUSCA	7	23	4	13	3	22
(Gastropoda)	(2)	(2)	(2)	(4)	(1)	(1)
(Scaphopoda)	(2)	(7)	—	—	—	—
(Pelecypoda)	(3)	(14)	(2)	(9)	(2)	(21)
ARTHROPODA	10	166	4	96	—	—
(Pycnogonida)	(3)	(12)	—	—	—	—
(Isopoda)	(4)	(19)	(2)	(93)	—	—
(Amphipoda)	(2)	(134)	(2)	(3)	—	—
(Brachyura)	(1)	(1)	—	—	—	—
ECHINODERMATA	9	244	4	24	11	57
(Asteroidea)	(1)	(16)	(1)	(2)	(3)	(5)
(Ophiuroidea)	(5)	(208)	—	—	(2)	(37)
(Holothurioidea)	(2)	(2)	(3)	(22)	(4)	(9)
(Echinoidea)	(1)	(28)	—	—	(2)	(6)
PROCHORDATA	1	21	1	1	—	—
(Ascidiacea)	(1)	(21)	(1)	(1)	—	—

* Larger, arenaceous forms, excluding many specimens of minute calcareous forms, attached to the polychaete tubes.

** Excluding inumerable specimens of a polychaete species (Maldanidae?), living in a slender, sand bearing tube.

bottom; since several epibiotic organisms such as a capurellid amphipod and a sponge were found in association with the tubes. Besides these polychaete tubes, the following forms were conspicuous at this station; many individuals of several ophiurans and a capurellid amphipod with red colouration and several specimens of an irregular echinoid, an asteroid with a protuberance (epiroctal cone) at the center of the back (*Ctenodiscus*) and a pelecypod (*Portlandia*). At St. E_2 in the Japan Trench, a whitish, spiny isopod crustacean (*Eurycope* type) was most numerous. Polychaetes (*Macellicephala* type and others),

holothurians (*Elpidia* type and others), a pelecypod (*Spinula* n. sp.) and an elongated actiniarian with dark-coloured, tough cuticle (*Galatheanthemum* type?) were also common in the Japan Trench. On the flat bottom at St. E_6, globose holothurians (*Scotoplanes* type, 2 species) and a holothurian with flat sole and a prominent caudal appendage (*Psychropotes*) were very conspicuous for their large size and curious shapes. Ophiurans and a pelecypod (*Spinula oceanica*) were also present in conspicuous numbers.

During the operation on the sea mount at St. E_4, the teeth-bearing iron bars, which had formed the front edges of the outside frame of the rectangular dredge were broken off; the inside frame was packed full of extraordinarily large manganese nodules, and was deformed into the shape of a round basket. The bottom was torn out of the canvas bag at the rear end. A few dendritic bryozoan colonies attached to the manganese nodules were the only animals collected by the dredge.

Thanks are due to Dr. J. C. DAN of the Ochanomizu University for her help in preparing the manuscript.

References

SUYEHIRO, Y., E. IWAI, M. ISHINO and M. HORIKOSHI (1960): Benthic animals. in SUYEHIRO *et al* (1960): Notes on the sampling gears and the animals collected on the second cruise of the Japanese Expedition of Deep Seas (JEDS-2). *Oceanogr. Mag.*, **11** (2), 187–198, 2 pls., 8 figs., 6 tables. (188–191).

Fig. 6.1. Benthic animals collected by the beam-trawl. (Photo. by Mr. F. SEKI) **1.** Asteroid with the epiproctal cone (*Ctenodiscus*, 5 cm: St. E 1, 1,700 m). **2.** Polychaete tube with other animals collected at St. E 1. **3.** Deep sea holothurian (Elpidiidae, 3. 5 cm: St. E 2, 6,700–7,400 m). **4.** Isopod crustacean (*Eurycope*, 4.5 cm: St. E 2). **5.** Deep sea polychaete (*Macellicephala*, 5 cm: St. E 2). **6.** Two speceis of pelecypod (*Spinula oceanica* & *Tindaria*, 3 specimens on the right hand) and a buccinid gastropod (White object-1 cm; St. E 6, 5,655 m). **7.** Globose holothurian (*Scotoplanes*, 2 spp. ?. 8 cm: St. E 6). **8.** Holothurian with a caudal appendage (*Psychropotes*, ventral view: Scale-30 cm: St. E 6).

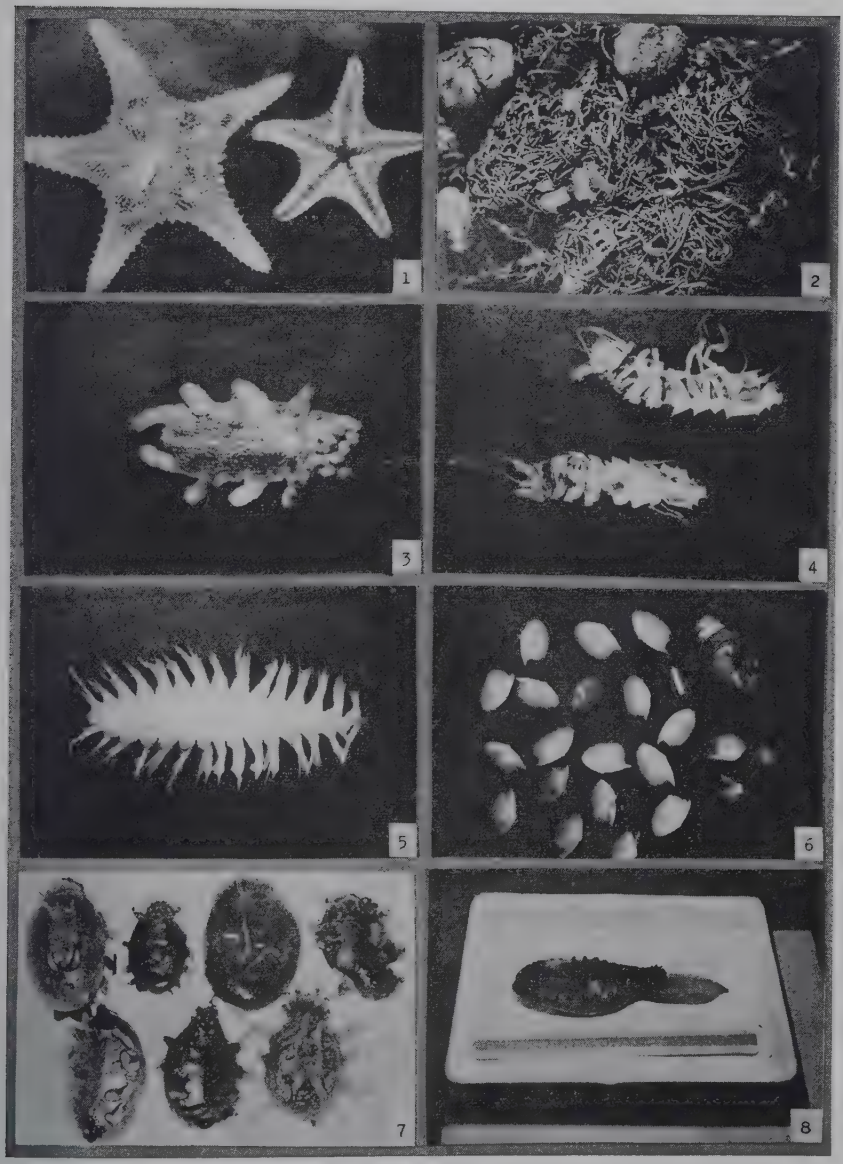

Fig. 6.1.

The Oceanographical Magazine
Vol. 13. No. 2, March 1962

VII. Geological Results in the Japanese Deep Sea Expedition in 1961 (JEDS-4)*

By

Noriyuki Nasu** and Takahiro Sato***

Abstract: Approximately 500 kilometers along the line of 38°N off the Pacific coast of northeastern Honshu was surveyed.

The axis of the Japan Trench was crossed at the depth of about 7,460 meters at about 144° E, and a seamount of which height is approximately 2,450 meters was newly found at about 146° E. The existence of the "Japanese Pacific Sea-shelf" along the west slope of the Japan and Kurile Trenches which had been visualized by the past three deep sea expeditions off Japan since 1959 was again assured on the western slope of the trench at the depth between 1,500 and 1,800 meter. Hilly configurations were found at the deeper portion than 3,000 meters on the western slope of the Trench. The trench bottom shows often flat topography having the width of 2~3 kilometers. The eastern slope has also hilly configuration. There is a kind of gentle rise of about 250 kilometers in width at the Pacific Basin proper just east side of the Trench. This part is quite flat having the depth of 5,300 to 5,700 meters except the newly discovered Ryofu seamount situated at the middle.

Gravels and blue mud with sand were obtained by a piston corer and by a trawl at the depth of approximately 1,700 meters on the "Japanese Pacific Sea-shelf". Sand and mud of obvious terrigenous origin was sampled by a piston corer at the west slope of the Trench fairly close to the trench bottom. Several hundreds of gravels including well rounded sedimentary rocks with terrigenous sand and mud slightly mixed with pelagic red clay were collected on the eastern trench slope also fairly close to the bottom. At the eastern margin of the Trench, sand and mud mixture of terrigenous origin including pelagic red clay were sampled by a piston coring.

Pelagic red clay with a few manganese nodules were collected by a piston corer at a point twelve kilometers apart from the west skirt of the seamount. Four gigantic boulders thickly coated by manganese compounds were obtained by a dredge on southeastern slope of the seamount. A column of red clay perhaps inserted by layers of volcanic ashes was obtained by a piston corer at the very flat surface of the Pacific Basin, 200 kilometers east of the seamount; in the vicinity, also several thousands of rounded pumice pebbles and manganese nodules were collected by a trawl.

The coarse sediments on the eastern slope of the trench might had been brought into the present position prior to the subsidence of the trench axis or might be transported by ice rafting.

* JEDS Contribution No. 35.

** Geological Institute, University of Tokyo.

*** Hydrographic Office of Japan.

1. *Introduction*

The fourth Japanese Deep Sea Expedition (JEDS-4) was carried during 5th to 30th of June in 1961. This paper presents a preliminary report on geology of this expedition. The each detail will be published later.

There were four geologists among the scientists on board of Ryofu-Maru, observation ship of the Japan Meteorological Agency. They were as follows:

Noriyuki Nasu	General geology	Geol. Inst., Univ. of Tokyo
Kei Oshite	Fossil and living diatoms	Geol. Sec., Hokkaido Gakugei Univ.
Takahiro Sato	General geology	Hydrogr. Office
Tooru Shirai	Organic contents in sediments	Geol. Inst., Univ. of Kyoto

Sampling devices were two piston corers, a dredge, a trawl net and a piston corer for heat flow measurements.

First of all, the writers thank to Dr. Kei Oshite and Mr. Tooru Shirai for their cooperation, also to the scientific members on board for their assistances, especially for echogram readings.

The writers are indebted to the Japan Meteorological Agency and the Deep Sea Research Committee of Japan, especially to Drs. Kiyoo Wadachi, Kazuhiko Terada, Jotaro Masuzawa, Ryuzo Marumo, Tadashi Yasui and to Mr. Hideo Akamatsu of the Japan Meteorological Agency. The writers appreciate the cooperation of the Captain and all crew members of the Ryofu-Maru. Also, Misses Haruko Komada and Yasuko Hosoi assisted the preparation for the manuscript, as well as in the laboratory.

2. *Topography*

The depth sounding was recorded by a deep sea echo-sounder which had been also used for the past three Japanese Deep Sea Expeditions. The ship location was determined mostly by Loran.

All depths described in this paper are uncorrected ones presuming the echo speed of 1,500 m/sec in sea water.

The echo soundings were recorded continuously when the ship was cruising and the depths were read by every 10 minute. Also, the records were taken fairly continuously even when the ship was stationed for the observation.

The range of the survey was along the line of 38 N between 142 10′ E

and 148° E approximately. The distance was about 500 kilometers. The truck of the ship is presented in Figure 7.1; and the depths beneath the solid thicker line in the Figure are projected on the verical plane along 38° N. The result is shown in Figure 7.2 as a profile of the surveyed line.

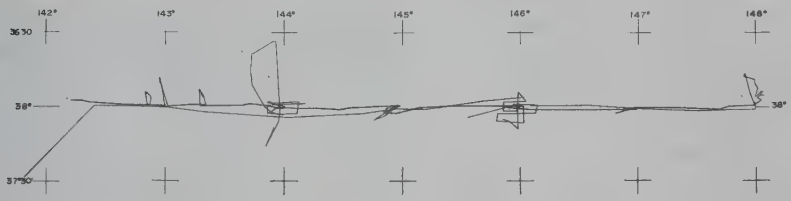

Fig. 7.1. The course of Japanese Deep Sea Expedition, the Fourth (JEDS-4) by Ryofu-Maru. The soundings under the thicker solid line are shown in Figure 7.2.

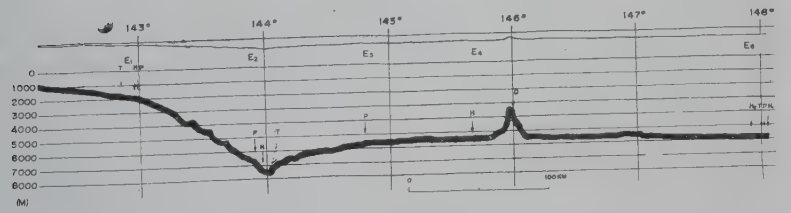

Fig. 7.2. The sounding profile along the latitude 38° N. off the coast of Onagawa, northeast Honshu. Upper half: true scale, Lower half: 1/10. P: piston core, T: trawl, D: dredge, H: heat flow measurement.

The profile starts from the depth of several hundreds meters off the coast of Onagawa, northeast Honshu, Japan, and crosses the Japan Trench and enters further into the flat characteristic Pacific Ocean floor. A seamount, not flat-topped was discovered in the vicinity of 38° N, 146° E.

(1) Japanese Pacific Sea-shelf

Flat and wide terrace-like areas ranging between about 1,500 and 3,000 meters deep have been found through the past three Japanese Deep-Sea Expeditions on the western slopes of the Japanese and Kurile Trenches (Nasu *et al.*, 1960 a, b). The senior writer has proposed the name of "Japanese Pacific Sea-shelf" for this flat terraces (Nasu, 1961 a, b). The slope shallower than

this "shelf" is defined as the continental slope and that deeper is defined as the trench slope in this paper.

Along the line of 38° N, the profile had been taken only to the depth of 2,340 meters (JEDS-2-S) from the coast in 1959; this profile was extended to the east by the present expedition.

There is a very flat terrace of 7 kilometers wide at the depth of 1,550 meters, and also another gently tilted terrace of 8 kilometers wide is recognized at the depth between 1,700 and 1,800 meters. Sampling location E_1 is on the latter terrace.

The existence of such flat sea-shelf on the continental slopes had already been pointed out at the Philippine Basin side of the southwest Honshu (TAYAMA, 1950).

(2) *Trench*

The slope angle between 1,800 and 3,100 meters deep along the western trench slope is about 2°35′, and the slope between 3,100 and 5,600 meters deep shows up-and-down feature showing the mean angle of 3°10′ and having peaks at the depths of 3,600, 4,300 and 5,150 meters; each of them has the height of approximately 100～150 meters.

The slope angle from 5,600 meters to the trench bottom of which depth is 7,400 meters is 4°10′, and there are three flat terraces at the depths of 5,650 (1 km wide), 6,250 (3 km wide) and 6,500 (2 km wide) meters. The trench bottom is quite flat and is approximately 2.5 kilometers in width.

The deepest point in the vicinity is located between 38°01.2′ N, 144°01.2′ E and 38°00.8′ N, 144°00.0′ E, and the depth is 7,460 meters.

There is a steep slope from the trench bottom to the depth of 7,050 meters showing the mean angle of 20° on the eastern slope of the trench. Hilly configuration is also recognized on the eastern slope between 7,050 and 5,400 meters deep. The mean angle is 2°50′ between 7,050 and 6,300 meters, and is 0°55′ between 6,300 and 5,400 meters.

There is a sudden fall of about 100 meters in height from west to east at 5,850 meters in depth; this may be a fault.

As the trench is defined as the range between the eastern margin of the Japanese Pacific Sea-shelf and the upper limit of the eastern slope, the width of the Japan Trench here is about 160 kilometers. Sampling station E_2 is close to the trench bottom: piston coring was made on the west slope and trawling

was carried on the east slope and both of them were fairly close to the trench bottom. Sampling location E_3 is at the upper margin of the eastern trench slope.

(3) Ocean Bottom

There is a flat ocean bottom ranging 5,300 to 5,400 meters deep beyond the eastern margin of the trench, and the depth becomes slightly deeper ranging 5,600 to 5,700 meters further beyond 250～300 kilometers east of the trench margin. There is a gentle rise having the width of 300 kilometers beyond the trench.

A newly found seamount is located approximately 100 kilometers east of the trench margin, and a seahill is seen further 100 kilometers east of the seamount (39°59.5′ N, 147°01.8′ E). The east side of this seahill forms a steep slope of 120 meters in height descending toward east. This may also be a fault.

Generally speaking, the ocean bottom is very flat in contrast to the hilly configuration in the trench.

Sampling location E_4 is about 12 kilometers apart from the west skirt of the above-mentioned seamount and the sediment was obtained by a piston corer attached to the heat flow measuring equipment.

Sampling location E_6 is the eastern margin of the surveyed line and is in the middle of the flat Pacific Basin bottom.

(4) Ryofu Seamount

An isolated seamount was discovered in the vicinity of 38° N, 146° E. Figure 7.3 shows the plan. The figure of this seamount in the profile of Figure 7.2 is a profile cut by 38° N line so that it naturally presents a smaller figure than the profile crossing the peak.

This seamount is named as the "Ryofu Kaizan (Seamount)". It is conical in general, but the upper half is slightly elongated along the east west direction. The surrounding ocean bottom is about 5,250 to 5,300 meters in depth.

The depth of the peak is 2,830 meters. The peak is sharp so that it is not a guyot. The height of the mount is about 2,450 meters. The location of the peak is 37°59.5′ N, 145°57.8′ E.

The long axis is 21 kilometers along the east-west direction at the depth

of 5,000 meters, and the short axis along north-south direction is 14.5 kilometers.

The detailed profile of this seamount will be described in later paper.

Southeastern slope of this seamount was dredged. This is the sampling location E_4; the course is shown in Figure 7.3 as a zig-zag route, and the depth of dredging was 3,600~3,400 meters.

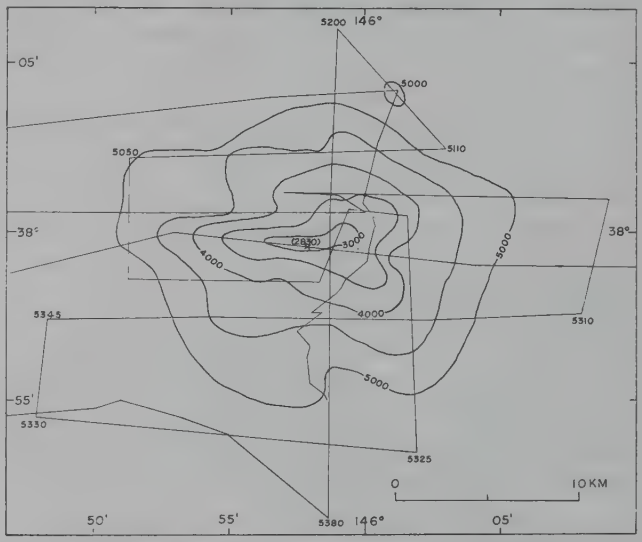

Fig. 7.3. The topography of a newly found "Ryofu Seamount." Depth in meters. The course of the ship is also shown.

3. Sediments

The bottom samplings were made by two large piston corers, a small one which attached to a heat flow measuring apparatus, one biological dredge and a trawl net. The following table shows the sampling position, depth, date, and type of apparatus of each location. Among the table, P means piston coring, T is trawling, D is dredging and H means heat flow measurement.

Consequently, there were 4 piston corings, 3 trawlings, 1 dredging, 1 piston coring with heat flow measuring and 2 attached samples outside of the heat flow apparatus; or, there were 3 samplings on the west slope of the Trench,

Station	Position N	Position E	Uncorrected Depth (M)	Date (1961)
E_1T	38°00.3′	142°52.5′	1,690	6—7
	38°05.0′	142°52.0′	1,650	
E_1P	38°03.0′	142°59.0′	1,800	6—7
E_2T	38°00.0′	144°05.0′	6,700	6—8～9
	37°57.0′	143°59.4′	7,340	
E_2P	38°00.0′	143°55.2′	6,935	6—11
E_3P	37°59.7′	144°52.0′	5,430	
E_4H	37°56.0′	145°40.0′	5,350	6—21
E_4D	38°59.3′	146°00.1′	3,175	6—27～28
	38°00.9′	145°59.9′	3,450	
E_6P	38°03.6′	148°00.6′	5,625	6—24
E_6H_1	38°04.0′	148°03.0′	5,645	6—25
E_6H_2	38°12.0′	147°55.0′	5,610	6—26
E_6T	38°06.4′	148°01.0′	5,655	6—26
	38°11.2′	147°59.0′	5,650	

2 on the east slope, 5 on the Pacific Basin proper and 1 on the seamount.

The sediments collected at each sampling location were as follows:

(1) E_1T

Mixture of sand and mud of terrigenous origin was obtained. Several subangular gravels of 2 to 3 centimeters in diameters including rounded sedimentary rocks were also collected. There were several wood fragments, too. This location as well as the following one are situated on the Japanese Pacific Sea-shelf.

(2) E_1P

A piston corer of 6 meters long (effective length was 4 meters) was used. Sample of 205 centimeters in length was obtained in the main tube, and the core catcher of the pilot corer caught the sediment too. Blue mud with sand was obtained.

(3) E_2T

This location is on the eastern slope of the Trench and fairly close to the trench axis. Many gravels with terrigenous sand and mud were obtained. Slightly, pelagic red clay was contaminated. Gravels were rounded hard sedimentary rock (10.5 cm), subrounded siltstones (16.3 cm, 12.7 cm), subangular siltstones (10.5 cm, 9 cm, 9cm), subrounded pumice (11 cm), angular hard rock (7.5 cm), angular coal (9 cm) and numerous small pieces of siltstone and

pumice. Total number will easily be more than one thousand. Also, two pieces of bamboo, 22 cm and 14 cm in length, were obtained with several wood fragments. Those gravels, plant pieces and a part of small gravels are shown in Figure 7.4. The scale is 50 centimeters in length.

Fig. 7.4. Gravels and plant fragments collected at E_2T station. Scale is 50 cm long. For example, sample no. 1 is a hard sedimentary rock.

(4) E_2P

This station is on the west slope of the trench close to the trench bottom. The length of a piston corer was also 6 meters and its effective length was 4 meters.

There were 324 centimeters sediment core in the main tube, and more than 23 centimeters in the pilot corer.

Mostly the sediment was bluish green mud with reddish brown ones of a few centimeters thick at the bottom surface, which might had been resulted by the oxidation.

(5) E_3P

This location is situated at the eastern margin of the Trench. The length of a piston corer was arranged in 6 meters long (effective part was 4 meters long).

The obtained core samples were 258 centimeters long in the main tube and 45 centimeters long in the pilot corer. The deposit is a mixture of terrigenous blue mud and pelagic red clay with some content of sand.

(6) E_4H

This point is approximately 12 kilometers apart from the Ryofu Seamount and situated in the flat Pacific Basin bottom. Sediment column of 187 centimeters long was collected in a small size piston corer, which is 3 meters in length and attached to a heat flow measuring instrument. The sediment was red clay and the influence of terrigenous materials could not be seen any more. There were also three manganese nodules of black brown oolitic feature; two (4.4 cm, 2.7 cm) were tangled on the lead line outside the tube, and one (4 cm) was laid at the surface of the core sediment.

(7) E_4D

Southeastern slope of the Ryofu Seamount was sampled by a biological dredge. Four large boulders thickly coated by manganese compounds were obtained which were shown in Figure 7.5. Their sizes were 53 cm, 45 cm, 42 cm and 30 cm. The detail of those boulders will be reported in later paper.

(8) E_6P

This point is just middle of the flat Pacific Basin proper. A piston corer of 11 meters long of which effective length is 8 meters was used, and could get 404.5 centimeters core in the main tube and 69.5 centimeters core in the pilot corer.

The obtained sediment was pelagic red clay and seemed to be inserted by layers of volcanic ashes.

(9) E_6H_1 and E_6H_2

Pelagic red clay was attached on the surface of heat flow measuring appratus which had no piston corer.

(10) E_6T

Several thousands of gravels were collected by a net trawl. Those are mostly pumice pebbles coated by manganese oxides and manganese nodules. Surface color is black brown, and their sizes are several centimeters. Those are shown in Figure 7.6.

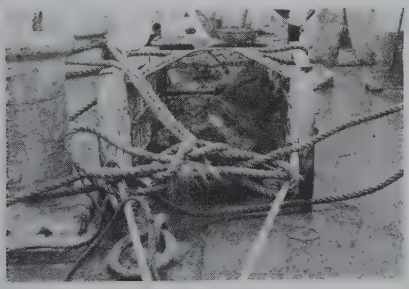

Fig. 7.5. Manganese boulders in a dredge collected at E_4D station on the southeastern slope of the Ryofu Seamount.

Fig. 7.6. Manganese coated pumice fragments and manganese nodules collected at E_6T station. Scale is 50 cm long.

One artificial iron fragment of few centimeters was contaminated. This might be introduced during the Second World War.

There were no rounded sedimentary pebbles.

4. Provenance of the coarse sediments

During the Japanese Deep Sea Expedition in 1959 (JEDS-1 & 2) the existence of widely distributed coarse sediments on the bottom surface of the western slopes of Japan Trench and of the southern part of Kurile Trench were recognized (Nasu *et al.*, 1960 a, b). Subangular basalt pebbles were collected from the depth of 8,450 (corrected) meters in the Ramapo Deep (Station JEDS-1-R in 1959), being associated with sand and red clay. A well-rounded pebble of hard sandstone was obtained at the southern extreme of Kurile Trench from the depth of 8,005 meters (corrected) (Station JEDS-2-C_2 in 1959), being associated with sand and blue mud.

Several hundreds of pebbles and gravels were also obtained at the Station JEDS-2-S in 1959 from the depth of 2,230 to 2,350 meters off the Coast of Onagawa, along the Pacific Coast of Northeast Japan. These were well rounded, subrounded and angular gravels, and were consisted of sedimentary, igneous and metamorphic rocks. The maximum size was 44 centimeters in diameter (Iijima and Kagami 1960, Kagami and Iijima, 1960).

This JEDS-2-S Station is a little east of the Japanese Pacific Sea-shelf so that there can be three possibilities so far as the provenance of those gravels at this station is concerned. They are as follows:

(1) Japanese Pacific Sea-shelf may be a submerged ancient wave-cut terrace, and the above-mentioned coarse sediment at the JEDS-2-S Station might had been originated on this terrace then might be brought into the station by submarine land slides for short distances.

The time of wave cutting might be sometimes around Pliocene because of the ages of diatom contents in gravels. Afterwards the Sea-shelf might be subsided into the present level.

(2) The gravels might be transported from land to the present position by ice rafting during the ice ages in Pleistocene.

(3) The gravels might be brought down by the modern turbidity currents from the present-day shallow water to the present resting position.

At the present, the possibility can be considered as the above successive order (Nasu 1961, a, b, c; Nasu *et al.*, 1960 b). There are also atrong opinion to support the first possibility (Iijima, 1961 a, b; Iijima et al, 1960). The coarse sediments in the Ramapo Deep might be brought into the deep by submarine slides and these in the Kurile Trench might be brought also

by submarine slides/or ice rafting (Nasu *et el.*, 1960 b).

Those coarse sediments collected during the past expeditions had been obtained from the west slopes of the Trenches and never on the east slope. It seems to be a significant result that the coarse sediments were also obtained on the east slope during this expedition at the station JEDS-4-E_2 by trawling (Nasu, 1961 c).

The followings are possible provenances of those coarse sediments in the Trench conducted by the results of the JEDS-4 Expedition.

(1) Terrigenous sand and mud are widely distributed on the west slope of the Japan Trench as well as on the east. Gravels are also widely distributed. The content of pelagic red clay is increased at the eastern margin of the Trench.

(2) Coarse sediments including gravels were collected at the Station JEDS-2-S in 1959, where is a little east of the "Japanese Pacific Sea-shelf." Coarse sediments involving gravels were ascertained this time to exist on this "Sea-shelf" by trawling (JEDS-4-E_1). The surface of this "Sea-shelf" may be covered by abundant amount of coarse sediments.

(3) There can be three possible explanations for the occurrence of the gravels on the east slope close to the trench bottom.

(i) These gravels had been supplied to the present position by submarine slides possibly from the west prior to the subsidence of the trench axis. Afterwards, the trench axis was subsided leaving the gravels on the east slope of the trench. Since then, almost there have been no deposition on that station.

(ii) Those gravels were transported by ice rafting during the ice ages in Pleistocene.

(iii) Those gravels were transported by turbidity current comparatively in recent years. The current flowed down on the west slope, crossed the trench axis, and creeped up the east slope for several hundreds of meters before it came to the resting position.

At the present, the writers are considering the above mentioned possibilities in successive order. In case of the first possibility, it can be also considered that the trench axis was much shallower than the present depth at the time when the "Japanese Pacific Sea-shelf" was formed perhaps by wave cutting; gravels at E_2T station might be

brought by submarine slides possibly from the vicinity of the "Sea-shelf."

(4) Coarse sediments contaminated in blue mud and red clay at the eastern margin of the Trench (E_3 station) might be brought by turbidity currents from the west prior to the subsidence of the trench axis/or brought by ice rafting during ice ages/or brought by volcanic activity in the vicinity.

(5) Only red clay, including a little amount of volcanic ashes, pumice fragments, manganese nodules were obtained on the flat Pacific Basin floor beyond the trench.

Ice rafted coarse sediments were not obtained this time in these areas. It could be possible to get these sediments in these areas if the coarse sediments in the trench were originated by ice rafting.

One of the writers once got gravels possibly brought by ice rafting during ice ages further northeast of the present areas under the investigation (KUNO, FISHER and NANU, 1956).

References

IIJIMA, A. (1961a): Origin of the continental slope off northeastern Japan. *Tenth Pacific Science Congress, Abstract Papers*, p. 373.

——, (1961b): Cainozoic Tectonic development of the continental slope, northeast of Japan. *Jour. Geol. Soc. Japan*, **67** (793), pp. 561–577 (in Japanese with English Résumé).

IIJIMA, A. and H. KAGAMI (1960): Large gravels collected from the depth of 2,230 meters off Shiogama. (abs.). *Jour. Geol. Soc. Japan*, **66** (778), p. 455 (in Japanese).

KAGAMI, H. and A. IIJIMA (1960): On the bottom sediments off Onagawa and Kushiro, the adjacent continental slope of Japan Trench. *The Ocenogr. Mag., Cent. Meteorol. Agency*, **11** (2), pp. 233–242, or *Rep. JEDS*, **1**, pp. 233–242.

KUNO, H., R. L. FISHER and N. NASU (1956): Rock fragments and pebbles dredged near Jimmu Seamount, Northwestern Pacific. *Deep-Sea Res.*, **3**, pp. 126–233.

NASU, N. (1961a): Kaitei (Submarine Bottom). "*Chikyu no Kosei* (Structure of the Earth)" (Tsuboi, ed.), Iwanami Book Co., pp. 113–141 (in Japanese).

—— (1961b): The provenance of coarse sediments recently discovered on the shelf and the trench slopes off the Japanese Pacific Coast. *Tenth Pacific Science Congress, Abstract Papers*, pp. 381–382.

—— (1961c): Relict coarse sediments in the Japan Trench. *Abstracts of the 20th Anniversary Meeting, Oceanogr. Soc. Japan*, pp. 47–48.

——, A. IIJIMA and H. KAGAMI (1960a): Geological results in the Japanese Dees Sea Expedition in 1959. *The Oceanogr. Mag., Cent. Meteorol. Agency*, **11** (2), pp. 201–214, or *Rep. JEDS*, **1**, pp. 201–214.

——, A. IIJIMA, T. SATO, K. KOBAYASHI, H. NIINO and T. SAKAMOTO (1960b): Japanese Deep Sea Expedition by Ryofu Maru. (abs.), *Jour. Geol. Soc. Japan*, **66** (778), p. 454 (in Japanese).

TAYAMA, R. (1950): Submarine configuration off Shikoku, especially continental slope. *Bull. Hydrogr. Office Japan.* Special number, No. 7, pp. 54–82 (in Japanese).

The Oceanographical Magazine
Vol. 13. No. 2, March 1962

Ⅷ. Report on Geomagnetic Survey during JEDS-4 Cruise*

By

Seiya Uyeda**, Masashi Yasui***, Ki-iti Hôrai** and Takeo Yabu**

During the JEDS-4 cruise and a subsequent cruise, a total geomagnetic field survey was carried out with the aid of a proton magnetometer developed by the Research Group for Proton Magnetometer[1),2)]. The instrument used in the present work is the all-transistorized one which was originally constructed for field surveying.[2)] A special fish (Fig. 8.1), towed behind the ship by a 100 m long teflon covered coaxial cable, was made for the sea work. The fish contains only the coil and no pre-amplifier. The signal wave, after amplification, is mixed with the standard frequency signal (either 2.0 kc or 1.9 kc) provided by quartz crystal oscillators. The beat waves, usually less than 100 c/s and the standard 40 c/s wave are, after a power amplification, fed to a two component pen-writing oscillograph. Using the 40 c/s wave as the timer, one can read the beat frequency, and consequently, the total magnetic force. The measurement was conducted at every thirty minutes automatically during the voyage. When considered necessary, manual readings were also taken with shorter intervals.

Fig. 8.1. The fish.

Fig. 8.2 shows the paths of the cruises and the contour lines of equal total field intensity. It seems that the general trend already established in

* JEDS Contribution No. 36.

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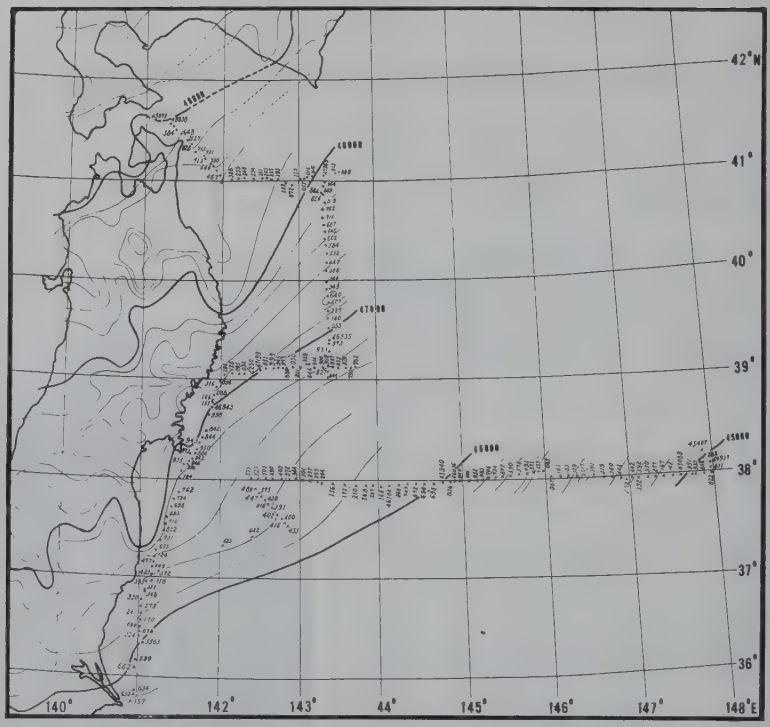

Fig. 8.2. The path of the cruises and the general contour lines of equal total field intensity.

the inland of Japan does extend to the Pacific Ocean.[3] Further surveys are of course necessary to discuss the details.

Fig. 8.3 shows the variation in the total force along the 38°N parallel from 142°E to 148°E. The values plotted are the direct readings of the measurements. In the lower part of the figure the corresponding topographic section is indicated. The deep at 144°E is the Japan Trench and the rise at 146°E is the sea mount Ryofu discovered by the JEDS-4. The field intensity decreases eastward from about 46800 γ to 44800 γ on the line covered. Superimposed on this general trend, it seems that there is an anomaly of several hundred gammas over the Japan Trench. The field intensity shows a rise

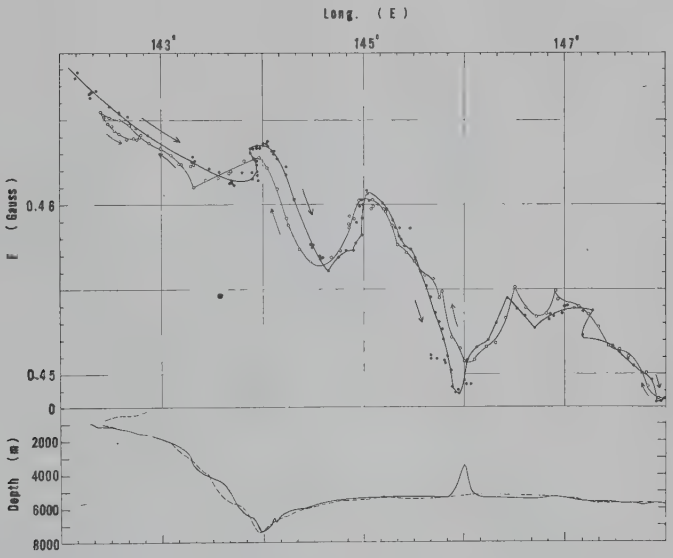

Fig. 8.3. The variation in the total force along the 38°N parallel from 142°E to 148°E.

just above the deepest point of the Trench. It rises at about 145°E to probably slightly above the normal again. The other sharp decrease noted at 146°E is due to the sea mount and is obviously a very local feature. Whether or not the above described anomaly, somewhat displaced eastward from the topografic profile, is really associated with the Trench is not certain at the present stage of knowledge. It would be required to make such Trench crossing surveys at different latitudes and to see if such anomaly pattern extends all along the Trench.

Over the sea mount Ryofu, a detailed geomagnetic survey was made simultaneously with the sounding survey. In this the readings were taken at every six minutes. From evenly distributed 96 readings thus obtained the contour map of total force distribution as shown in Fig. 8.4 was drawn. In this map, the thin lines indicate the topography of the sea mount. The normal value of the total force being estimated from the general trend in Fig. 8.3 as about 45400 γ, the sea mount seems to produce a notable negative anomaly of some $-500\,\gamma$ just north of the summit of the cone. The magni-

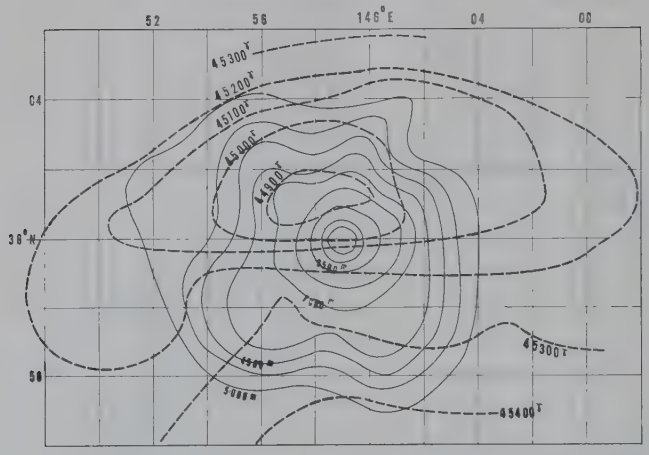

Fig. 8.4. Total force distribution around the sea mount.

tude of the anomaly is fairly large considering that the level of the plane where the field measurement was made was about 3000 m above the summit. But it appears to be rather puzzling that the anomaly is marked only in the negative sense, since a volcanic mass magnetized in the direction of the present geomagnetic field is expected to produce a positive anomaly in the southern side of the summit and a less pronounced negative anomaly in the northern side. Fig. 8.5 is the cross section of the topography and the magnetic profile parallel to the meridian passing through the summit. The absence of the positive anomaly in the southern side may be clearly observed. The dotted line in the figure is the calculated curve of the total force when a spherical mass with the same volume as the cone of the present sea mount, magnetized in the direction of the geomagnetic field is placed its center on the sea floor. The intensity of magnetization in the calculation is assumed to be of the order of 1×10^{-2} emu/cc, which is the same as the intensity of the natural remanent magnetization of basaltic lava of Volcano Mihara, Oshima Island.[4] The magnitudes of the calculated positive and negative anomalies are 1500 γ and 600 γ.

All the data obtained so far are listed in the Table 8.1 and Table 8.2, where the ship's positions determined by Loran are also indicated. Positions at times between two Loran determinations were obtained by interpolation.

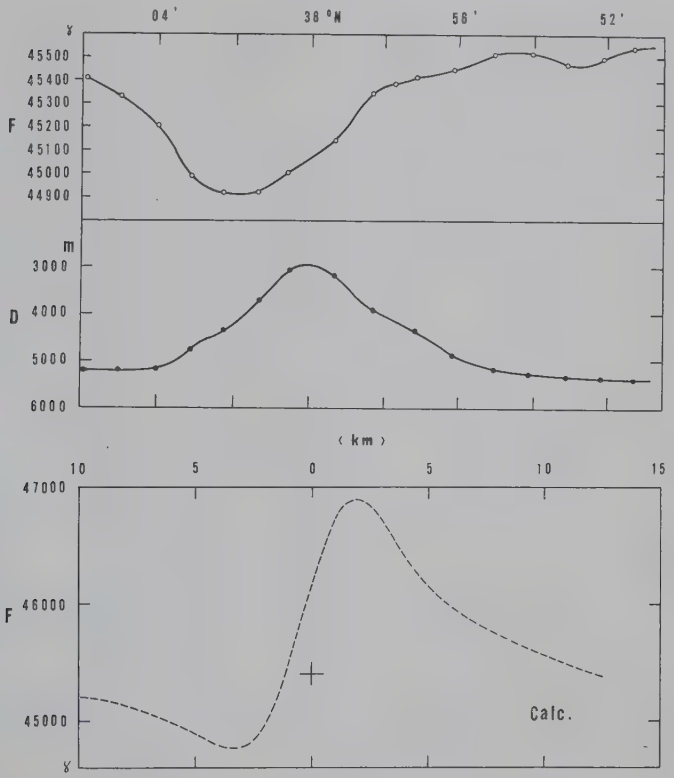

Fig. 8. 5. Cross section of the topography, magnetic profile parallel to the meridian passing through the summit and the calculated curve of the total force.

Finally the authors would like to express their thanks to Dr. T. Rikitake and Mr. I. Tanaoka for instrumentation and the crew of m. s. Ryofu-Maru for their assistance.

References

1) Research Group for Proton Magnetometer. *Bull. Earthq. Res. Inst., Tokyo Univ.*, **36**, 433 (1958).
2) Research Group for Proton Magnetometer. *Bull. Earthq. Res. Inst., Tokyo Univ.*, **38**, 125 (1960).
3) Communication from Geographical Survey Institute, Ministry of Construction, Japan.
4) T. Nagata, "Rock Magnetism" 1st ed., Maruzen, Tokyo, 1953.

Table 8-1.

No.	Date	Time	Standard cycle	Lat. (N)	Long. (E)	Cycle	Total force
1	June 6	13h 45m	2.0kc	37°12.0′	141°39.1′	1977.0kc	46432.0γ
2		55	1.9	37°12.0′	141°39.1′	1977.8	46451.6
3		56	2.0	37°12.0′	141°39.1′	1976.4	46418.7
4		15 00	2.0	37°30.6′	141°46.6′	1978.8	46475.1
5		45	2.0	37°38.6′	141°50.1′	1981.2	46531.5
6		48	2.0	37°39.2′	141°50.5′	1981.2	46531.5
7		17 00	2.0	37°51.5′	141°53.5′	1984.4	46606.6
8		18 47	2.0	38.02.5′	142°09.1′	1990.7	46754.6
9		52	2.0	38°02.5′	142°10.4′	1992.0	46785.1
10		19 30	2.0	38°02.5′	142°17.5′	1986.4	46653.6
11		36	2.0	38°02.5′	142°17.9′	1985.6	46634.8
12		39	1.9	38°02.3′	142°18.5′	1987.	46667.7
13		20 00	1′9	38°02.0′	142°21.5′	1987.5	46679.4
14		30	2.0	38°01.5′	142°29.0′	1983.3	46580.8
15		21 00	2.0	38°01.2′	142°34.5′	1981.9	46547.9
16		30	2.0	38°01.1′	142°40.2′	1980.9	46524.4
17		22 00	2.0	38°01.0′	142°45.2′	1978.0	46456.3
18		30	2.0	38°00.8′	142°52.0′	1976.3	46416.4
19	June 8	02 25	2.0	38°03.6′	143°17.3′	1971.2	46296.6
20		25	1.9	38°03.6′	143°17.3′	1971.3	46300.0
21		30	2.0	38°03.0′	143°17.4′	1971.1	46294.2
22		03 00	2.0	38°00.5′	143°19.5′	1969.7	46261.4
23		03 38	2.0	38°00.8′	143°28.0′	1967.9	46218.4
24		50	2.0			1967.2	46202.6
25		04 00	2.0	38°01.2′	143°33.8′	1967.1	46199.6
26		30	2.0	38°01.1′	143°40.5′	1964.2	46132.2
27		50	2.0	38°01.3′	143°41.3′	1964.3	46134.5
28		52	2.0	38°01.4′	143°41.5′	1964.9	46148.6
29		54	1.9	38°01.4′	143°41.6′	1964.0	46127.5
30		05 00	2.0	38°01.5′	143°42.5′	1963.6	46118.1
31		30	2.0	38°00.8′	143°47.5′	1966.7	46190.9
32		06 00	2.0	38°00.5′	143°52.5′		
33		05	2.0	38°00.4′	143°53.1′	1966.8	46193.2
34		07	1.9	38°00.3′	143°53.4′	1965.0	46151.0
35		10	2.0	38°00.2′	143°53.7′	1976.9	46430.5
36		12	2.0	38°00.1′	143°54.0′	1976.9	46430.5
37		15	2.0	38°00.3′	143°54.3′	1969.9	46266.1
38		30	2.0	37°59.8′	146°56.2′	1970.2	46273.1
39	June 10	15 08	2.0	38°25.6′	143°55.6′	1972.8	46334.2
40		10	1.9	38°25.3′	143°55.7′	1972.2	46320.1
41		30	2.0	38°22.8′	143°56.0′	1969.1	46247.3
42		16 02	2.0	38°18.7′	143°56.5′	1966.7	46189.7
43		03	2.0	38°18.6′	143°56.5′	1967.1	46200.3
44		30	2.0	38°15.2′	143°56.9′	1968.9	46242.6
45	June 16	17 00	2.0	38°01.0′	144°01.7′	1974.2	46367.0
46		10	2.0	38°01.6′	144°02.7′	1973.8	46357.7
47		12	2.0	38°01.8′	144°02.9′	1973.6	46353.0

No.	Date	Time	Standard cycle	Lat. (N)	Long. (E)	Cycle	Total force
48	June 18	20h 45m	2.0kc	37°57.3′	143°52.2′	1971.8kc	46310.7γ
49		47	2.0	37°57.3′	143°52.2′	1971.9	46311.9
50		21 00	2.0	37°57.4′	143°52.2′	1972.9	46335.4
51		15	2.0	37°58.5′	143.54.0′	1973.0	46338.9
52		30	2.0	37°59.6′	143°55.8′	1973.2	46343.6
53		31	2.0	37°59.6′	143°55.9′	1973.4	46348.3
54		45	2.0	37°59.9′	143°57.9′	1973.0	46338.9
55		47	2.0	37°59.9′	143°58.2′	1973.2	46343.6
56		22 00	2.0	37°59.7′	144°00.3′	1974.2	46367.0
57		33	2.0	37°59.5′	144°05.3′	1972.1	46317.7
58		45	2.0	37°59.5′	144°05.8′	1971.8	46310.7
59		46	2.0	37°59.5′	144°06.0′	1971.5	46303.6
60		23 00	2.0	37°59.5′	144°08.3′	1970.2	46273.1
61		30	2.0	37°59.6′	144°13.3′	1968.4	46230.8
62		32	2.0	37°59.6′	144°13.6′	1966.4	46183.9
63	June 19	00 00	2.0	37°59.6′	144°18.2′	1960.1	46035.9
64		30	2.0	37°59.3′	144°23.1′	1954.9	45913.8
65		59	2.0	37°59.0′	144°27.8′	1948.9	45772.8
66		01 00	2.0	37°59.0′	144°28.0′	1948.4	45761.1
67		04	2.0	37°59.1′	144°38.7′	1948.1	45754.1
68		29	1.9	37°59.8′	144°23.3′	1945.7	45697.7
69		30	1.9	37°59.8′	144°33.5′	1945.5	45693.0
70		02 00	1.9	38°00.0′	144°38.8′	1942.2	45615.5
71		32	1.9	38°00.3′	144°44.5′	1945.6	45695.3
72		59	1.9	38°00.5′	144°49.3′	1947.1	45730.6
73		03 25	1.9	38°00.5′	144°53.3′	1947.1	45730.6
74		26	1.9	38°00.5′	144°54.8′	1949.2	45779.9
75		40	1.9	38°00.5′	144°55.5′	1954.3	45899.7
76		50	1.9	38°00.5′	144°57.0′	1958.4	45996.0
77		59	2.0	38°00.5′	144°58.4′	1959.9	46031.2
78		04 00	1.9	38°00.5′	144°58.5′	1951.1	45824.5
79		10	2.0	38°00.8′	144°58.5′	1955.4	45925.5
80		11	1.9	38°00.8′	144°58.5′	1958.8	46005.4
81	June 20	05 24	1.9	37°58.5′	145°01.8′	1962.2	46085.2
82		26	2.0	37°58.6′	145°01.9′	1961.9	46075.8
83		30	1.9	37°58.7′	145°02.7′	1959.9	46031.2
84		32	2.0	37°58.8′	145°03.0′	1959.9	46031.2
85		59	2.0	37°59.9′	145°07.9′	1958.9	46007.7
86		06 14	2.0	37°59.9′	145°10.6′	1959.4	46019.4
87		16	1.9	37°59.9′	145°11.0′	1959.2	46014.8
88		30	2.0	38°00.0′	145°13.6′	1957.8	45981.9
89		45	1.9	38°00.0′	145°16.3′	1955.3	45923.2
90		47	1.9	38°00.0′	145°16.6′	1955.1	45918.5
91		47	2.0	38°00.0′	145°16.6′	1954.9	45913.8
92		07 00	2.0	38°00.0′	145°19.0′	1953.0	45869.1
93		00	2.0	38°00.0′	145°19.0′	1953.1	45871.5
94		10	2.0	38°00.2′	145°20.7′	1950.8	45817.5
95		12	2.0	38°00.2′	145°21.0′	1949.3	45872.2
96		15	2.0	38°00.3′	145°21.5′	1950.2	45803.4

No.	Date	Time	Standard cycle	Lat. (N)	Long. (E)	Cycle	Total force
97		07h 30m	2.0kc	38°00.6′	145°24.0′	1948°5kc	45763.4γ
98		30	1.9	38°00.6′	145°24.0′	1948.2	45756.4
99		45	1.9	38°00.6′	145°27.0′		
100		45	2.0	38°00.6′	145°27.0′	1953.0	45869.1
101		48	2.0	38°00.6′	145°27.6′	1947.6	45742.3
102		48	1.9	38°00.6′	145°27.6′	1947.3	45735.3
103		08 00	2.0	38°00.6′	145°30.1′	1945.5	45693.0
104		00	1.9	38°00.6′	145°30.1′	1945.0	45681.2
105		16	1.9	38°00.6′	145°33.3′	1941.7	45603.7
106		34	1.9	38°00.6′	145°36.9′	1938.1	45526.2
107		45	1.9	38°00.6′	145°39.2′	1935.4	45455.8
108		58	1.9	38°00.6′	145°41.8′	1931.4	45361.8
109		59	1.9	38°00.6′	145°42.0′	1931.1	45361.8
110		09 15	1.9	38°00.6′	145°44.7′	1929.2	45310.2
111		28	1.9	38°00.6′	145°46.8′	1927.5	45270.2
112		29	1.9	38°00.6′	145°47.0′	1924.9	45209.2
113		31	1.9	38°00.6′	145°47.3′	1924.7	45204.5
114		45	1.9	38°00.6′	145°49.6′	1920.6	45110.5
115		58	1.9	38°00.6′	145°51.8′	1917.1	45026.0
116		10 15	1.9	38°00.6′	145°56.0′	1912.4	44915.6
117		17	1.9	38°00.6′	145°56.5′	1911.5	44894.4
118		27	1.9	38°00.6′	145°59.2′		
119		30	2.0	38°00.6′	146°00.0′	1915.0	44976.6
120		36	1.9	38°00.6′	146°01.6′	1913.7	44943.8
121		45	1.9	38°00.6′	146°04.0′	1913.5	44941.4
122		14 43	1.9	38°01.2′	145°57.8′	1909.7	44852.2
123		48	1.9	38°01.2′	145°58.8′	1910.1	44861.6
124		54	1.9	38°01.2′	146°00.0′	1911.0	44882.7
125		15 00	1.9	38°01.2′	146°01.1′	1912.5	44917.9
126		03	2.0	38°01.2′	146°01.7′	1923.2	45169.2
127		06	1.9	38°01.1′	146°02.3′	1914.1	44955.5
128		12	2.0	38°01.1′	146°03.5′	1917.9	45042.4
129		18	1.9	38°01.1′	146°04.7′	1918.7	45063.5
130		24	1.9	38°01.0′	146°05.9′	1920.2	45098.8
131		30	1.9	38°01.0′	146°07.0′	1921.3	45124.6
132		36	1.9	38°01.0′	146°08.2′	1922.0	45141.1
133							
134							
135		42	1.9	38°00.9′	146°08.7′	1922.7	45157.5
136		43	1.9	38°00.8′	146°08.6′	1923.5	45173.9
137		48	1.9	38°00.4′	146°08.0′	1924.7	45204.5
138		54	1.9	38°00.0′	146°07.2′	1925.7	45228.0
139		16 00	1.9	37°59.6′	146°06.4′	1926.9	45253.8
140		06	1.9	37°59.1′	146°05.6′	1927.3	45265.5
141		12	1.9	37°58.7′	146°04.8′	1927.3	45265.5
142		18	1.9	37°58.3′	146°04.1′	1928.7	45298.4
143		19	2.0	37°58.2′	146°03.9′	1927.0	45258.5
144		24	1.9	37°57.8′	146°03.3′	1927.2	45263.2
145		29	1.9	37°57.5′	146°02.6′	1926.1	45237.3

No.	Date	Time	Standard cycle	Lat. (N)	Long. (E)	Cycle	Total force
146		16h 30m	2.0kc	37°57.4′	146°02.5′	1925.4kc	45220.9γ
147		36	1.9	37°57.4′	146°00.9′	1925.8	45230.3
148		42	1.9	37°57.4′	145°58.3′	1927.6	45272.6
149		48	1.9	37°57.5′	145°57.7′	1928.7	45296.1
150		54	1.9	37°57.5′	145°56.1′	1928.7	45296.1
151		17 00	1.9	37°57.5′	145°54.5′	1927.7	45249.1
152		06	1.9	37°57.5′	145°53.3′	1924.5	45197.4
153		12	1.9	37°57.5′	145°52.0′	1923.0	45164.5
154		18	1.9	37°57.4′	145°50.8′	1922.5	45152.8
155		24	1.9	37°57.4′	145°49.5′	1922.8	45159.8
156		30	1.9	37°57.4′	145°48.3′	1923.5	45176.3
157		36	1.9	37°56.4′	145°48.2′	1924.5	45199.8
158		42	1.9	37°55.7′	145°48.1′	1925.1	45213.9
159		48	1.9	37°54.8′	145°47.9′	1925.5	45220.9
160		48	1.9	37°54.8′	145°47.9′	1925.5	45220.9
161		18 00	1.9	37°54.4′	145°49.9′	1926.5	45246.7
162		03	1.9	37°54.4′	145°50.5′	1927.6	45272.6
163		12	1.9	37°54.2′	145°52.3′	1929.1	45307.8
164		18	1.9	37°54.2′	145°53.5′	1930.3	45336.0
165		24	1.9	37°54.1′	145°54.7′	1931.9	45373.6
166		30	1.9	37°54.0′	145°55.9′	1933.3	45406.5
167		36	1.9	37°54.0′	145°57.1′	1934.3	45429.9
168		42	1.9	37°53.9′	145°58.3′	1935.0	45446.4
169		48	1.9	37°53.8′	145°59.5′	1935.1	45448.7
170		54	1.9	37°53.8′	146°00.7′	1934.7	45439.3
171		19 00	1.9	37°53.7′	146°01.9′	1935.3	45453.4
172		01	2.0	37°53.9′	146°01.9′	1937.6	45507.4
173		06	1.9	37°54.7′	146°01.9′	1934.0	45422.9
174		12	1.9	37°55.7′	146°01.8′	1931.5	45364.2
175		18	1.9	37°56.8′	146°01.8′	1928.8	45300.8
176		24	1.9	37°57.8′	146°01.7′	1926.9	45256.1
177		30	1.9	37°58.8′	146°01.7′	1925.3	45218.6
178		36	1.9	37°59.8′	146°01.6′	1920.7	45110.5
179		42	1.9	38°00.5′	146°01.2′	1914.7	44969.6
180		48	1.9	38°00.7′	145°59.8′	1912.5	44917.9
181		54	1.9	38°00.2′	145°59.1′	1915.9	44997.8
182		20 00	1.9	37°59.3′	145°58.7′	1922.5	45152.8
183		06	1.9	37°58.5′	145°58.3′	1929.1	45260.8
184		12	1.9	37°58.5′	145°56.9′	1928.6	45296.1
185		18	1.9	37°58.5′	145°55.5′	1935.8	45465.2
186		24	1.9	37°58.6′	145°54.1′	1925.8	45230.3
187							
188		30	1.9	37°58.6′	145°52.7′	1923.9	45185.7
189		34	1.9	37°58.6′	145°51.8′	1922.5	45152.8
190		36	1.9	37°58.6′	145°51.3′	1923.5	45176.3
191		42	1.9	37°59.5′	145°51.3′	1920.6	45108.2
192							
193		48	1.9	38°00.4′	145°51.3′	1919.1	45072.9
194		49	1.9	38°00.6′	145°51.3′	1919.5	45082.3

No.	Date	Time	Standard cycle	Lat. (N)	Long. (E)	Cycle	Total force
195		20h 54m	1.9kc	38°01.3′	145°51.3′	1920.8kc	45112.9γ
196		21 00	1.9	38°02.2′	145°51.3′	1924.3	45195.1
197		06	1.9	38°02.2′	145°46.5′	1921.4	45127.0
198		12	1.9	38°02.3′	145°41.6′	1918.7	45063.5
199		18	1.9	38°02.3′	145°36.8′	1916.1	45002.5
200		24	1.9	38°02.3′	145°32.0′	1913.9	44950.8
201		30	1.9	38°02.4′	145°27.1′	1912.9	44927.3
202		31	2.0	38°02.4′	145°26.3′	1912.3	44913.2
203		36	2.0	38°02.4′	145°23.3′	1913.1	44932.0
204		42	1.9	38°02.4′	145°17.5′	1913.1	44932.0
205		48	1.9	38°02.4′	145°12.7′	1914.2	44957.9
206		54	1.9	38°02.5′	145°07.8′	1916.1	45002.5
207		22 00	1.9	38°02.5′	145°03.0′	1917.7	45040.1
208		06	1.9	38°02.1′	145°15.2′	1918.1	45049.5
209		12	1.9	38°01.7′	145°25.4′	1917.7	45040.1
210		18	1.9	38°01.4′	145°36.6′	1919.8	45089.4
211		24	1.9	38°01.0′	145°47.8′	1927.9	45279.6
212		26	1.9	38°00.9′	145°51.5′	1924.8	45206.8
213		26	2.0	38°00.9′	145°51.5′	1928.0	45282.0
214		30	1.9	38°00.6′	145°59.0′	1929.3	45312.5
215		36	1.9	38°00.6′	145°58.9′	1925.9	45232.7
216		42	1.9	38°00.6′	145°58.9′	1920.5	45105.8
217		48	1.9	38°00.6′	145°58.9′	1915.7	44993.1
218		52	1.9	38°00.5′	145°58.8′	1913.9	44950.8
219		54	1.9	38°00.5′	145°58.8′	1912.6	44920.3
220		23 00	1.9	38°00.5′	145°58.7′	1912.5	44917.9
221		01	2.0	38°00.5′	145°58.7′	1912.9	44927.3
222		06	1.9	38°00.5′	145°58.7′	1916.5	45011.9
223		12	1.9	37°59.4′	145°58.7′	1922.3	45148.1
224		18	1.9	37°58.4′	145°58.7′	1926.5	45246.7
225		21	1.9	37°58.7′	145°58.7′	1928.5	45293.7
226		24	1.9	37°57.3′	145°58.7′	1929.5	45317.2
227		27	1.9	37°56.8′	145°58.7′	1931.1	45354.8
228		30	1.9	37°56.3′	145°58.7′	1933.9	45420.5
229		33	1.9	37°55.7′	145°58.7′	1935.8	45465.2
230		36	1.9	37°55.2′	145°58.7′	1933.9	45420.5
231		39	1.9	37°54.7′	145°58.7′	1934.5	45434.6
232		42	1.9	37°54.3′	145°58.7′	1937.1	45495.7
233		48	1.9	37°53.4′	145°58.7′	1936.7	45486.3
234		54	1.9	37°52.4′	145°58.7′	1937.6	45507.4
235		55	1.9	37°52.4′	145°58.7′	1937.2	45498.0
236	June 21	00 00	1.9	37°51.5′	145°58.7′	1939.5	45552.1
237	June 22	08 10	1.9	37°57.2′	145°39.3′	1920.9	45115.2
238		12	2.0	37°57.3′	145°39.7′	1920.2	45098.9
239		30	1.9	37°58.0′	145°43.2′	1920.1	45096.4
240		55	1.9	37°59.0′	145°48.0′	1919.7	45087.0
241		57	1.9	37°59.1′	145°48.4′	1918.9	45068.2
242		09 27	1.9	38°00.0′	145°53.0′	1912.9	44927.3
243		10 00	1.9	37°59.7′	146°01.3′	1919.8	45089.4

No.	Date	Time	Standard cycle	Lat. (N)	Long. (E)	Cycle	Total force
244		10h 30m	1.9kc	37°59.4′	146°07.5′	1923.1kc	45166.9γ
245		11 00	1.9	37°59.1′	146°13.7′	1924.9	45209.2
246		30	1.9	37°59.1′	146°19.8′	1929.1	45307.8
247		12 00	1.9	37°59.0′	146°25.8′	1935.5	45458.1
248		30	1.9	37°59.0′	146°31.2′	1932.7	45392.4
249		13 00	1.9	37°59.0′	146°36.6′	1930.8	45347.7
250		32	1.9	37°59.0′	146°42.0′	1928.2	45286.7
251		14 16	1.9	37°59.1′	146°50.6′	1930.0	45328.9
252		30	1.9	37°59.1′	146°53.3′	1930.8	45347.7
253		59	1.9	37°59.2′	146°58.8′	1931.5	45364.2
254	June 23	10 30	1.9	37°57.8′	146°50.8′	1929.4	45314.9
255		35	2.0	37°57.9′	146°51.6′	1931.4	45361.8
256		11 00	1.9	37°58.5′	146°55.5′	1931.4	45361.8
257		37	1.9	37°59.8′	147°01.3′	1933.4	45408.8
258		12 00					
259		03	1.9	37°59.9′	147°05.5′	1933.0	45399.4
260		31	1.9	37°59.9′	147°10.9′	1932.2	45380.6
261		13 00	1.9	37°59.9′	147°16.5′	1932.2	45380.6
262		01	1.9	37°59.9′	147°16.3′	1931.0	45352.4
263		30	1.9	37°59.8′	147°10.8′	1926.2	45239.7
264		14 00	1.9	37°59.5′	147°28.2′	1923.4	45173.9
265		30	1.9	37°59.3′	147°32.9′	1921.7	45134.0
266		58	1.9	37°59.2′	147°36.8′	1920.0	45094.1
267		15 30	1.9	37°59.0′	147°41.2′	1918.6	45061.2
268		16 00	1.9	38°00.1′	147°46.5′	1916.7	45016.6
269		30	1.9	38°00.1′	147°52.1′	1915.0	44976.6
270		17 00	1.9	38°00.1′	147°57.6′	1909.4	44845.1
271		01	1.9	38°00.1′	147°57.8′	1909.4	44845.1
272		13	1.9	38°00.1′	147°59.5′	1909.4	44845.1
273		14	1.9	38°00.1′	147°59.5′	1910.2	44863.9
274	June 26	06 06	1.9	38°12.9′	147°54.4′	1933.3	45406.5
275		30	1.9	38°09.2′	147°56.5′	1928.0	45282.0
276		07 00	1.9	38°05.2′	147°59.2′	1913.3	44936.7
277		30	1.9	38°02.0′	147°59.4′	1908.8	44831.0
278		08 00	1.9	37°58.8′	147°59.5′	1908.4	44821.6
279		01	1.9	37°58.8′	147°59.3′	1908.4	44821.6
280		30	1.9	37°58.8′	147°53.3′	1909.0	44835.7
281		09 00	1.9	37°58.8′	147°47.2′	1912.7	44922.6
282		30	1.9	37°58.7′	147°46.6′	1915.6	44990.7
283		10 00	1.9	37°58.5′	147°36.1′	1919.8	45089.4
284		30	1.9	37°58.4′	147°30.6′	1922.0	45141.1
285		11 00	1.9	37°58.6′	147°24.5′	1923.1	45166.9
286		31	1.9	37°58.8′	147°18.2′	1927.8	45277.3
287		33	1.9	37°58.8′	147°17.8′	1928.0	45282.0
288		12 00	1.9	37°58.9′	147°12.3′	1930.9	45350.1
289		30	1.9	37°58.7′	147°06.7′	1932.7	45392.4
290		13 00	1.9	37°59.4′	147°01.1′	1933.1	45401.8
291		32	1.9	37°59.7′	146°53.4′	1934.8	45441.7
292		34	2.0	37°59.7′	146°53.0′	1936.9	45491.0

No.	Date	Time	Standard cycle	Let. (N)	Long. (E)	Cycle	Total force
293		14h 00m	1.9kc	38°00.1′	146°47.5′	1931.3kc	45359.5γ
294		30	1.9	38°00.4′	146°41.3′	1930.4	45338.3
295		15 00	1.9	38°00.8′	146°35.0′	1932.6	45390.0
296		30	1.9	38°00.8′	146°29.1′	1938.0	45516.8
297		16 00	1.9	38°00.8′	146°23.3′	1930.0	45328.9
298		30	1.9	38°00.8′	146°17.5′	1923.8	45183.3
299		17 00	1.9	38°00.8′	146°11.2′	1923.0	45164.5
300		30	1.9	38°00.7,	146°05.0′	1919.7	45087.0
301		18 00	1.9			1911.4	44892.1
302		30	1.9			1927.6	45276.2
303		37	1.9			1930.9	45350.1
304		45	1.9			1933.0	45399.4
305	June 28	05 35	1.9	38°04.1′	145°59·4′	1919.6	45084.7
306		06 00	1.9	38°04.0′	145°56.5′	1922.6	45155.1
307		30	1.9	38°03.5′	145°51.2′	1925.4	45220.9
308		07 00	1.9	38°03.0′	145°45.8′	1937.0	45493.4
309		00	1.9	38°03.0′	145°45.8′	1935.2	45451.1
310		30	1.9	28°02.0′	145°40.5′	1940.6	45577.9
311		30	2.0	38°02.5′	145°40.5′	1939.9	45561.5
312		08 00	1.9	38°01.8′	145°35.2′	1941.1	45589.6
313		30	1.9	38°01.1′	145°29.8′	1944.8	45676.5
314		09 00	1.9	38°00.5′	145°24.5′	1946.8	45723.5
315		30	1.9	38°00.1′	145°20.1′	1948.6	45765.8
316							
317		34	2.0	38°00.1′	145°19.5′	1948.6	45765.8
318		10 00	2.0	37°59.8′	145°15.8′	1953.6	45883.2
319		25	2.0	37°59.5′	145°12.1′	1957·6	45977.2
320		30	2.0	37°59.4′	145°11.4′	1957.8	45981.9
321		11 04	2.0	37°59.5′	145°05.8′	1958.4	45996.0
322		09	2.0	37°59.5′	145°04.9′	1957.7	45979.5
323		10	2.0	37°59.5′	145°04.8′	1958.0	45986.6
324		30	2.0	37°59.6′	145°01.5′	1960.1	46035.9
325		12 05	2.0	37°59.6′	144°55.6′	1960.1	46035.9
326							
327		31	2.0	37°59.0′	144°50.9′	1956.0	45939.6
328		32	2.0	37°59.0′	144°50.7′	1953.8	45887.0
329		33	2.0	37°58.9′	144°50.5′	1953.4	45878.5
330		13 00	2.0	37°58.3′	144°45.6′	1947.2	45732.9
331		32	2.0	37°57.6′	144°39.8′	1945.7	45697.7
332		33	1.9	37°57.6′	144°39.6′	1945.4	45690.6
333							
334		14 00	1.9	37°57.3′	144°34.0′	1945.4	45690.6
335		30	1.9	37°57.1′	144°27.7′	1944.6	45671.8
336		15 00	1.9	37°56.8′	144°21.5′	1947.8	45747.0
337		30	1.9	37°56.5′	144°15.0′	1953.8	45887.9
338							
339							
340		33	2.0	37°56.5′	144°14.3′	1955.4	45925.5
341		16 00	2.0	37°56.3′	144°08.5′	1963.0	46104.0

No.	Date	Time	Standard cycle	Lat. (N)	Long. (E)	Cycle	Total force
342		16h 30m	2.0kc	37°56.0′	144°02.0′	1968.2kc	46226.1γ
343		17 00	2.0	37°56.3′	143°55.3′	1970.8	46287.2
344		30	2.0	37°56.7′	143°48.7′	1970.0	46268.4
345		18 03	2.0	37°57.0′	143°41.2′	1967.5	46209.7
346		04	2.0	37°57.1′	143°41.2′	1967.3	46205.0
347		30	2.0	37°57.4′	143°34.3′	1965.9	46172.1
348		19 00	2.0	37°57.8′	143°26.7′	1965.2	46155.7
349		30	2.0	37°58.2′	143°19.0′	1963.4	46113.4
350		33	2.0	37°58.3′	143°18.3′	1969.8	46263.7
351		34	1.9	37°58.3′	143°18.1′	1969.2	46249.6
352		36	1.9	37°58.3′	143°17.7′	1969.6	46259.0
353		37	1.9	37°58.4′	143°17.5′	1969.0	46244.9
354		37	2.0	37°58.4′	143°17.5′	1968.7	46237.9
355							
356		20 02	1.9	37°58.9′	143°11.9′	1969.2	46249.6
357		03	2.0	37°58.9′	143°10.2′	1969.2	46249.6
358		30	2.0	37°59.5′	143°05.7′	1971.4	46301.3
359		21 00	2.0	38°00.2′	142°59.1′	1973.2	46343.6
360		30	2.0	38°00.3′	142°52.9′	1974.4	46371.7
361		22 00	2.0	38°00.2′	142°46.8′	1976.0	46409.3
362		30	2.0	38°00.5′	142°40.6′	1979.0	46479.8
363		23 00	2.0	38°00.5′	142°35.1′	1980.0	46503.3
364		30	2.0	38°00.5′	142°29.7′	1981.0	46526.8
365	June 29	00 00	2.0	38°00.5′	142°24.2′	1982.2	46554.9
366		30	2.0	37°58.1′	142°26.4′	1981.0	46526.8
367		01 00	2.0	37°55.6′	142°28.5′	1979.4	46489.2
368		30	2.0	37°53.2′	142°30.7′	1978.8	46475.1
369		02 00	2.0	37°50.8′	142°32.8′	1977.6	46446.9
370		30	2.0	37°48.4′	142°35.0′	1976.8	46428.1
371		03 00	2.0	37°45.9′	142°37.2′	1976.3	46416.4
372		30	2.0	37°43.5′	142°39.3′	1975.2	46390.5
373		04 00	2.0	37°41.1′	142°41.5′		
374		30	2.0	37°38.7′	142°43.6′	1975.7	46402.3
375		05 00	2.0	37°36.2′	142°45.8′	1975.6	46399.9
376		30	2.0	37°33.8′	142°47.9′	1976.3	46416.4
377		06 00	2.0	37°31.4′	142°50.1′	1977.0	46432.8
378		30	2.0	37°24.5′	142°26.2′	1977.4	46442.2
379		07 00	2.0	37°17.7′	142°02.3′	1976.6	46423.4
380		30	2.0	37°10.8′	141°38.4′		
381		08 00	2.0	37°04.0′	141°14.5′	1974.4	46371.7
382		30	2.0	36°59.5′	141°11.7′		
383		49	2.0	36°56.6′	141°10.0′	1973.8	46357.7
384		49	1.9	36°56.5′	141°10.0′	1974.0	46362.4
385		10 05	1.9	36°45.3′	141°03.4′	1972.2	46320.1
386		06	1.9	36°45.1′	141°03.4′	1972.3	46322.4
387		30	2.0	36°41.6′	141°03.0′	1971.3	46298.9
388		11 00	2.0	36°37.1′	141°02.5′	1968.9	46242.6
389		30	2.0	36°32.7′	141°02.0′	1965.8	46169.8
390		12 00	2.0	36°28.3′	141°01.5′	1962.4	46089.9

No.	Date	Time	Standard cycle	Lat. (N)	Long. (E)	Cycle	Total force
391		12h 10m	2.0kc	36°26.6′	141°01.4′	1960.0kc	46033.5γ
392		10	1.9	36°26.6′	141°01.4′	1961.9	46078.2
393		13	2.0	36°26.1′	141°01.3′	1961.8	46075.8
394		30	2.0	36°23.3′	141°01.0′	1959.6	46024.1
395		13h 00	2.0	36°18.3′	141°00.5′	1957.0	45963.1
396		30					
397		14 00	2.0	36.08.3′	140°59.5′	1953.8	45887.9
398		30	2.0	36°03.3′	140°59.0′	1952.7	45862.1
399		15 00					
400		53	2.0	35°49.5′	140°57.6′	1943.0	45634.3
401		54	1.9	35°49.0′	140°57.6′	1942.2	45615.5
402		16 00	1.9	35°48.3′	140°57.5′	1942.8	45629.6
403		36	1.9	35°43.8′	140°54.0′	1939.7	45556.8

Table 8.,2.

No.	Date	Time	Standard cycle	Lat. (N)	Long. (E)	Cycle	Total force
1	Sept. 7	17h 52m	2.0kc			2088.8kc	49058.6γ
2		55	2.0			2092.6	49147.8
3		58	2.0			2089.5	49075.0
4		18 30	2.0	41°32.0′	141°19.1′	2079.4	48837.8
5		40	1.9	41°31.0′	141°21.1′	2072.0	48664.0
6		19 00	1.9	41°29.0′	141°25.0′	2068.6	48584.2
7		05	2.0	41°28.6′	141°25.7′	2071.3	48647.6
8		30	2.0	41°26.3′	141°29.1′	2065.9	48520.8
9		20 00	2.0	41°23.7′	141°33.2′	2067.0	48546.6
10		30	2.0	41°20.1′	141°37.1′	2079.0	48828.4
11		21 00	2.0	41°16.5′	141°41.0′	2074.1	48713.3
12		30	2.0	41°14.0′	141°45.5′	2074.0	48711.0
13		36	2.0	41°13.5′	141°46.4′	2074.5	48722.7
14		22 00	2.0	41°11.5′	141°50.0′	2074.8	48729.8
15		30	2.0	41°08.7′	141°52.8′	2073.0	48687.5
16		23 00	2.0	41°06.0′	141°55.5′	2068.7	48586.5
17		30	2.0	41°03.0′	141°58.8′	2063.6	48466.7
18	Sept. 8	00 00	2.0	41°00.0′	142°02.0′	2059.4	48368.1
19		30	2.0	41°00.4′	142°07.8′	2057.7	48328.2
20		01 00	2.0	41°00.7′	142°13.5′	2056.0	48288.2
21		30	2.0	41°00.9′	142°19.0′	2054.3	48248.3
22		02 00	2.0	41°01.0′	142°24.5′	2053.7	48234.2
23		30	2.0	41°01.0′	142°29.8′	2052.7	48210.7
24		03 00	2.0	41°01.0′	142°35.0′	2055.0	48264.8
25		30	2.0	41°00.3′	142°40.0′	2054.6	48255.4

No.	Date	Time	Standard cycle	Let. (N)	Long. (E)	Cycle	Total force
26		04h 00m	2.0kc	41°00.5′	142°45.0′	2051.6kc	48184.9γ
27		30	2.0	40°58.9′	142°49.9′	2049.2	48128.5
28		05 00	2.0	40°57.3′	142°54.8′	2046.8	48072.2
29		30	2.0	40°58.6′	142°58.6′	2047.6	48081.6
30		52	2.0	41°00.9′	143°01.7′	2048.8	48119.1
31		52	1.9	41°00.9′	143°01.7′	2050.0	48147.3
32		06 00	2.0	41°01.0′	143°02.0′	2048.0	48100.4
33		30	2.0	41°01.7′	143°06.2′	2046.1	48055.7
34		07 01	2.0	41°02.3′	143°10.6′	2044.4	48015.8
35		02	1.9	41°02.3′	143°10.8′	2044.2	48011.1
36		30	2.0	41°02.6′	143°16.0′	2042.4	47968.8
37		08 00	2.0	41°02.8′	143°21.5′	2040.8	47931.2
38		30	2.0	41°03.4′	143°27.3′	2040.0	47912.5
39		09 00	2.0	41°09.3′	143°33.0′	2039.0	47889.0
40		20 15	2.0	41°01.6′	143°22.9′	2021.0	47466.2
41		30	1.9	40°59.7′	143°22.7′	2044.0	48006.4
42		30	2.0	40°59.7′	143°22.7′	2042.2	47964.1
43		21 00	2.0	40°56.0′	143°22.5′	2040.0	47912.5
44		30	2.0	40°51.6′	143°22.7′	2038.8	47884.3
45		35	2.0	40°50.2′	143°22.8′	2038.0	47865.5
46		36	1.9	40°50.1′	143°22.8′	2032.0	47724.6
47		37	2.0	40°49.9′	143°22.8′	2037.6	47856.1
48		37	1.9	40°49.9′	143°22.8′	2038.0	47865.5
49		22 00	2.0	40°46.0′	143°23.0′	2036.0	47818.5
50		30	2.0	40°41.4′	143°22.0′	2033.6	47762.1
51		23 00	2.0	40°36.8′	143°21.0′	2031.6	47715.7
52		30	2.0	40°32.4′	143°21.5′	2030.4	47687.0
53	Sept. 9	00 00	2.0	40°28.0′	143°21.9′	2028.6	47644.7
54		30	2.0	40°23.5′	143°22.0′	2026.8	47602.4
55		01 00	2.0	40°19.0′	143°22.0′	2026.0	47583.6
56		30	2.0	40°14.0′	143°22.5′	2023.8	47532.0
57		02 00	2.0	40°09.0′	143°23.0′	2020.2	47447.4
58		30	2.0	40°04.0′	143°23.0′	2017.6	47386.4
59		03 00	2.0	39°59.0′	143°23.0′	2015.8	47344.1
60		30	2.0	39°54.5′	143°23.1′	2016.0	47348.8
61		04 00	2.0	39°50.0′	143°23.2′	2028.4	47640.0
62		30	2.0	39°44.9′	143°23.4′	2027.0	47607.1
63		05 00	2.0	39°39.8′	143°23.5′	2010.8	47226.7
64		30	2.0	39°34.9′	143°23.5′	2007.1	47159.8
65		06 00	2.0	39°30.0′	143°23.5′	2003.4	47052.9
66		42	1.9	39°22.7′	143°24.1′	1998.4	46935.4
67		44	1.9	39°22.4′	143°24.2′	1999.4	46958.9
68		45	2.0	39°22.2′	143°24.2′	2000.0	46973.0
69		07 00	2.0	39°19.6′	143°24.4′	2000.0	46973.0
70		30	2.0	39°14.8′	143°24.9′	1998.3	46933.1
71		08 00	2.0	39°10.0′	143°25.3′	1997.2	46907.2
72		30	2.0	39°05.9′	143°26.0′	1993.8	46827.4
73			2.0			1990.2	46742.8
74		09 15	1.9	39°02.1′	143°27.0′	1986.0	46644.2

No.	Date	Time	Standard cycle	Lat. (N)	Long. (E)	Cycle	Total force
75		20h 07m	2.0kc	39°07.8′	143°43.5′	1991.0kc	46761.6γ
76		07	1.9	39°07.8′	143°43.5′	1991.8	46780.4
77		30	2.0	39°07.8′	143°40.2′	1992.2	46789.8
78		21 00	2.0	39°07.8′	143°36.0′	1993.5	46820.3
79		30	2.0	39°07.8′	143°30.5′	1994.9	46853.2
80		35	2.0	39°07.8′	143°29.6′	1994.7	46848.5
81			1.9			1992.4	46794.5
82		22 08	2.0	39°07.7′	143°23.5′	1996.5	46890.8
83		08	1.9	39°07.7′	143°23.5′	1994.7	46848.5
84		30	2.0	39°07.3′	143°19.3′	1996.9	46900.2
85		23 00	2.0	39°06.9′	143°13.5′	1997.5	46914.3
86		30	2.0	39°06.8′	143°07.9′	1998.1	46928.4
87		33	1.9	39°06.8′	143°07.3′	1994.6	46846.2
88	Sept. 10	00 00	2.0	39°06.8′	143°02.2′	1998.2	46930.1
89		30	2.0	39°06.9′	142°56.2′	1999.0	46949.5
90		01 00	2.0	39°07.0′	142°50.2′	2000.0	46973.0
91		07	1.9	39°07.0′	142°49.0′	1996.4	46888.4
92		10	1.9	39°06.9′	142°48.4′	1997.2	46907.2
93		30	1.9	39°06.7′	142°44.9′	1998.8	46944.8
94		02 00	1.9	39°06.7′	142°39.2′	2001.1	46998.8
95		30	2.0	39°05.9′	142°34.8′	1994.8	46850.3
96		03 00	1.9	39°05.2′	142°30.0′	2009.6	47198.5
97		30	1.9	39°04.1′	142°24.3′	2011.8	47250.1
98		04 00	1.9	39°03.0′	142°18.6′	2004.8	47085.7
99		30	1.9	39°03.0′	142°13.2′	2005.2	47095.1
100		05 00	1.9	39°03.0′	142°07.8′	2006.6	47128.0
101		30	1.9	39°02.4′	142°02.2′	2013.4	47287.7
102		06 00	1.9	38°58.0′	141°59.2′	1916.2	47353.5
103		30	1.9	38°54.0′	141°57.0′	1914.6	47315.9
104		07 00	1.9	38°50.1′	141°54.8′	1904.7	47083.4
105		28	2.0	38°45.7′	141°53.0′	2008.6	47175.0
106		30	2.0	38°45.3′	141°52.8′	2008.2	47165.6
107		08 01	2.0	38°40.4′	141°50.8′	1998.7	46942.5
108		01	1.9	38°40.4′	141°50.8′	1997.6	46916.6
109		30	1.9	38°36.6′	141°48.5′	2000.2	46977.7
110		31	2.0	38°36.4′	141°48.4′	2003.2	47048.2
111		09 00	2.0	38°28.6′	141°46.2′	1994.4	46841.5
112		30	2.0	38°24.7′	141°44.0′	1994.5	46843.8
113		10 00	2.0	38°20.8′	141°41.9′	1998.7	46942.5
114		30	2.0	38°16.1′	141°39.5′	1999.0	46949.5
115		39	1.9	38°14.7′	141°38.8′	1996.3	46886.1
116		40	2.0	38°14.5′	141°38.7′	2000.0	46973.0
117		41	2.0	38°14.4′	141°36.2′	1999.0	46949.5
118		42	1.9	38°14.2′	141°36.1′	1995.0	46855.6
119		11 00	2.0	38°11.4′	141°37.1′	1997.0	46902.5
120		30	2.0	38°09.7′	141°34.8′	1994.6	46946.1
121		37	1.9	38°08.0′	141°34.3′	1999.5	46961.2
122		39	2.0	38°08.2′	141°34.1′	1996.7	46895.5
123		39	1.9	38°08.2′	141°34.1′	2001.0	46996.5

No.	Date	Time	Standard cycle	Lat. (N)	Long. (N)	Cycle	Total force
124		11h 40m	2.0kc	38°08.1′	141°34.0′	1996.7kc	46895.5γ
125		12h 00	2.0	38°08.0′	141°32.5′	1995.0	46855.6
126		30	2.0	37°59.7′	141°30.7′	1991.8	46780.4
127		13 00	2.0	37°51.5′	141°29.0′	1991.0	46761.6
128		30	2.0	37°47.1′	141°27.0′	1989.4	46724.0
129		14 00	2.0	37°42.8′	141°25.0′	1988.3	46698.2
130		04	2.0	37°42.2′	141°24.7′	1988.3	46698.2
131		05	1.9	37°42.1′	141°24.7′	1988.3	46698.2
132		05	1.9	37°42.1′	141°24.7′	1986.0	46644.2
133		30	2.0	37°38.5′	141°23.0′	2000.0	46973.0
134		15 00	2.0	37°34.2′	141°21.0′	1985.1	46623.1
135		30	2.0	37°30.1′	141°19.6′	1988.8	46710.0
136		16 00	2.0	37°26.0′	141°18.2′	1994.0	46832.1
137		30	2.0	37°20.9′	141°16.2′	1989.7	46731.1
138		17 00	2.0	37°15.8′	141°14.2′	1985.2	46625.4
139		30	2.0	37°11.1′	141°12.5′	1980.9	46524.4
140		50	2.0	37°08.0′	141°11.5′	1978.9	46477.4
141		50	1.9	37°08.0′	141°11.5′	1976.1	46411.7
142		18 00	2.0	37°06.5′	141°10.8′	1977.7	46449.3
143		30	2.0	37°01.3′	141°08.9′	1976.6	46423.4
144		19 00	2.0	36°56.2′	141°07.0′	1975.3	46392.9
145		30	2.0	36°51.5′	141°06.6′	1973.5	46350.6
146		36	2.0	36°50.6′	141°06.6′	1973.4	46348.3
147		36	1.9	36°50.6′	141°06.6′	1970.9	46289.5

The Oceanographical Magazine
Vol. 13. No. 2, March 1962

IX. Heat Flow Measurements over the Japan Trench during the JEDS-4 *

By

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Terrestrial heat flow was measured at three localities along the 38°N parallel across the Japan Trench during the JEDS-4 cruise of M/S Ryofu-Maru. Stations E_1, E_2 and E_6 where heat flow was measured are shown in Fig. 9.1,

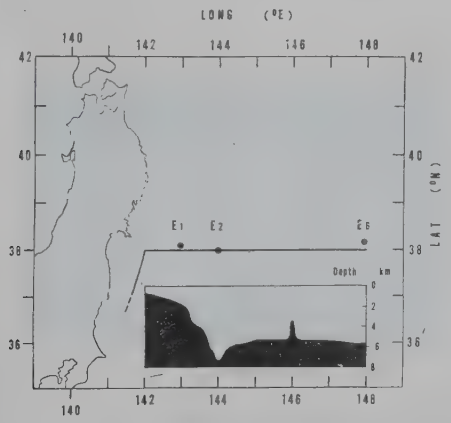

Fig. 9.1. Map indicating the stations E_1, E_2 and E_6 with the topographic section of the Japan Trench.

together with a topographic section of the Trench. The deep at 144°E is the Japan Trench and the rise at 146°E is the sea-mount Ryofu discovered by the JEDS-4. To obtain the heat flow through the sea bottom, a thermogradmeter[1] was used for measuring the thermal gradient; the thermal conductivity of

* JEDS Contribution No. 37.
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sediments recovered with a core sampler at the time of the gradient measurement was measured in the laboratory[2].

The temperature sensors in the present apparatus are two pairs of thermistors (**A**, **B** and α, β) contained in a steel probe 150 or 300 cm long. In order to obtain two temperature differences in the probe, the distance between thermistors **A** and **B** was made equal to the entire length of the probe, while thermistors α and β were placed in a lower segment of it[3]. Each pair of thermistors forms the two arms of an A. C. bridge, the other two arms partly consisting of a rotating continuous potentiometer. The temperature differences which correspond to the respective balancing positions of the two bridges are recorded on facsimile paper. The drum of the recording paper rotates with the same rate as the rotating potentiometers. Positions of the zero temperature difference in each bridge are determined by running the instrument in the deep sea water for some 10 minutes just before penetration into the bottom. Fig. 9.2 is an example of the records. The lines 0–0′ and 0″–0‴ are the zero

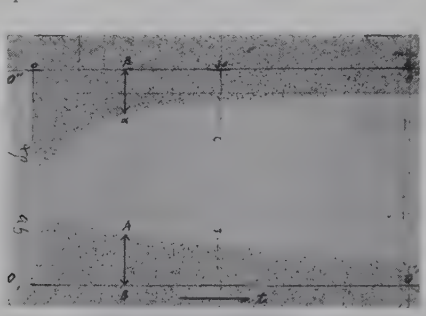

Fig. 9.2. Record of temperature differences at the station E_6.

lines and the distances **A**–**B** and α–β correspond to the temperature differences between the thermistors **A**–**B**, and α–β at a time t. The real temperature differences were read from the records by extrapolating the curve to $t \to \infty$ to eliminate the effect of the initial heating on penetration. The geothermal gradients thus obtained at three localities are listed in Table 9.1.

The thermal conductivity and water content of the specimens, which are blue mud at station E_1 and E_2 and red clay at E_6, were measured at every 12 cm along the cores. The average values for each locality together with the length of the core are shown in Table 9.1. The results of individual measurments are shown in Fig. 9.3.

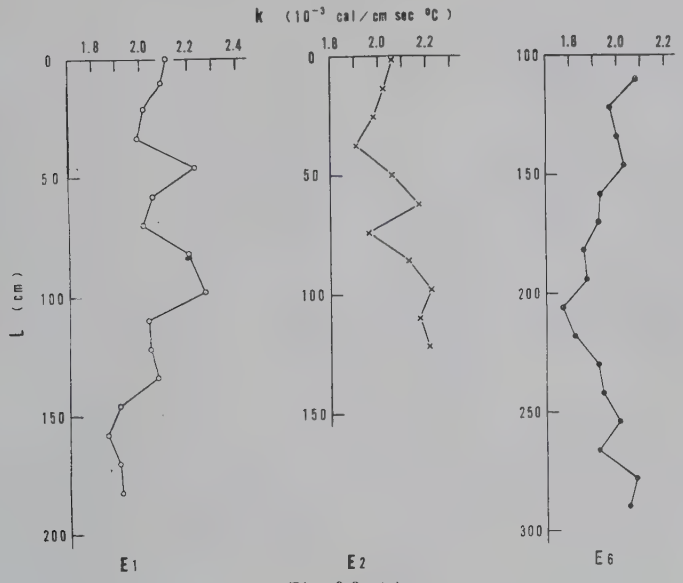

Fig. 9.3. (a)

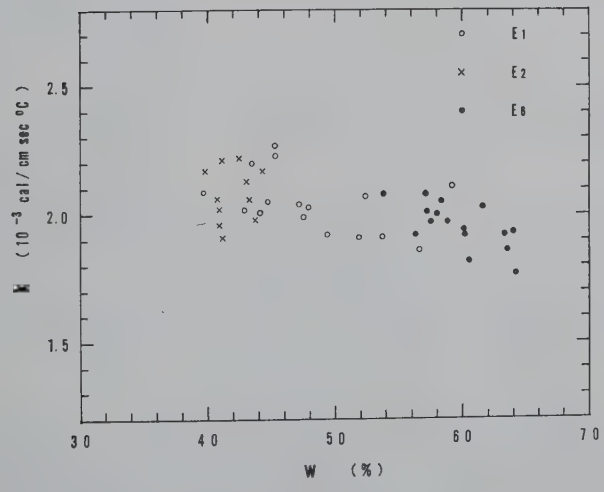

Fig. 9.3. (b)

Fig. 9.3. (a) Thermal conductivity of the sediments at every 12 cm along the cores.
(b) Diagram of thermal conductivity of sediments versus water content.

Table 9.1.

Station		E_1	E_2	E_6
Date	1961	June 7	June 15～16	June 26～27
Lat.	N	38°09′	37°59′	38°12′
Long.	E	142°58′	143°59′	147°55′
Water depth	m	1710	7345	5631
Geothermal gradient	°C/m	0.0130	0.0542	0.105
Core length	cm	184	124	184
Average thermal conductivity	10^{-3} cal/cm sec°C	2.10	2.11	1.95
Heat flow	10^{-6} cal/cm^2 sec	0.273	1.14	2.05

The values of heat flow (Table 9.1.) are, crossing the Trench from west to east, 0.273 μcal/cm^2 sec at station E_1, 1.14 μcal/cm^2 sec at station E_2 and 2.05 μcal/cm^2 sec at station E_6. It may be interesting to note that the lowest heat flow did not occur at the bottom of the Trench, but was found some 100 miles to the west on the inner side of the arc. This result seems to be in contrast to HERZEN's results obtained in the south-eastern Pacific[4]. The low heat flow value at station E_1, however, harmonizes quite well with the distribution of heat flow on the Japanese Islands determined by two of the authors (S. U. and K. H.)[5]. The average heat flow is low (less than 1.0 μcal/cm^2 sec) on the Pacific Ocean side of the Japanese Islands and is high (more than 2.0 μcal/cm^2 sec) on the Japan Sea side, except where the extension of the Mariana-Bonin arc meets the main Japan arc. This tendency is more pronounced in the northern part of Main Island of Japan, west of the location of present oceanic heat flow measurements. Many more measurements in the seas surrounding Japan are planned in the near future.

During the JEDS-4 cruise, seven trials for heat flow measurement were conducted. As has been described already, three of them were successful. Records of each trial will be summarized in Table 9.2.

The authors wish to express their thanks to Dr. T. RIKITITAKE for his encouragement. Their sincere thanks are also to the staff of the Department of Marine Meteorology, Japan Meteorological Agency and the crew of M/S Ryofu-Maru, for without their wholehearted cooperation and assistance this investigation could not have been completed.

Table 9.2.

Operation No.	Station	Date	Time at water surface	Time at penetration	Longitude	Latitude
IV—1	E_1	June 7	13 h 49 m	15 h 15 m	142°58′ E	38°09′ N
IV—2	E_2	June 11～12	23 h 45 m	04 h 12 m	144°01′ E	37°53′ N
IV—3	E_2	June 13～14	20 h 08 m		143°38′ E	37°48′ N
IV—4	E_2	June 15～16	14 h 22 m	19 h 15 m	143°58′ E	38°59′ N
IV—5	E_4	June 21～22	18 h 15 m	(21 h 10 m)	145°39′ E	37°56′ N
IV—6	E_6	June 24～25	19 h 50 m	00 h 19 m	148°03′ E	38°04′ N
IV—7	E_6	June 26～27	18 h 46 m	23 h 35 m	147°55′ E	38°12′ N

Operation No.	Station	Water depth	Wire length at penetration	Duration of stay of probe in bottom	Time of recovery	Apparatus
IV—1	E_1	1710 m	1690 m	60 min	17 h 40 m	R1
IV—2	E_2	7114 m	7150 m	63 min	11 h 25 m	R1
IV—3	E_2	5750 m			05 h 12 m	R1
IV—4	E_2	7345 m	7548 m	60 min	01 h 46 m	R1
IV—5	E_4	5360 m	(5271 m)	77 min	02 h 00 m	R2
IV—6	E_6	5668 m	5643 m	61 min	05 h 14 m	R1
IV—7	E_6	5631 m	5616 m	60 min	05 h 05 m	R1

Remarks to Table 9.2

Operation IV–1.....Successful.

Operation IV–2.....Penetration of the probe into sediments was not ascertained because the ball-breaker did not work. The record only showed the zero lines: it stopped before penetration probably because electrical leakage owing to humidity in the recorder.

Operation IV–3.....The apparatus did not reach the bottom this time: the ball-breaker did not work. The recorder did not stop, only showing the zero lines. The wire was released to 5883 m, whereas the water depth was 5665 m.

Operation IV–3.....Successful.

Operation IV–5.....Apparatus R2 was used. The probe penetrated into the sediments, though the time of penetration was uncertain. But the recorder stopped halfway, only showing the zero lines.

Operation IV–6.....The ball-breaker worked. The probe penetrated. But the time switch of the recorder did not work and no record was avairable.

Operation IV–7.....Completely successful.

References

1) S. Uyeda, Y. Tomoda, K. Hôrai, H. Kanamori and H. Futi (1961): *Bull. Earthq. Res. Inst., Tokyo Univ.*, **39**, 115.
2) K. Hôrai and S. Uyeda (1960): *Bull. Earthq. Res. Inst., Tokyo Univ.*, **38**, 199.
3) E. C. Bullard and A. Day (1961): *Geophys. Journ.*, **4**, 282.
4) R. P. von Herzen (1959): *Nature*, **183**, 882.
5) Uyeda, S. and K. Hôrai: Presented at the colloquium of the Earthquake Research Institute, Tokyo University, in September 27, 1961.

気象庁

欧文海洋報告

第 13 巻

THE OCEANOGRAPHICAL MAGAZINE

Vol. 13

Published by the Japan Meteorological Agency

1961-1962

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昭和37年3月25日印刷
昭和37年3月31日発行

編集兼発行人　気象庁
東京都千代田区大手町一ノ七

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東京都中央区新富町二ノ十九

印刷所　大東印刷工芸株式会社
東京都中央区新富町二ノ十九